Technical Memorandum

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South Sacramento County Agriculture and Habitat Lands Recycled Water, Groundwater Storage, and Conjunctive Use Program

Subject:	**Integrated Groundwater and Surface Water Modeling Results Technical Memorandum**
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Date:	August 7, 2017

This Integrated Groundwater and Surface Water Modeling Results Technical Memorandum (TM) describes the components and approach for integrated groundwater and surface water modeling of one project scenario representing the proposed South Sacramento County Agriculture and Habitat Lands Recycled Water, Groundwater Storage, and Conjunctive Use Program (South County Ag Program, Program, or Project). This modeling analysis was performed to support a Water Storage Investment Program (WSIP) grant application for the Program, prepared for the Sacramento Regional County Sanitation District (Regional San). The scenario is applied to two baseline scenarios representing 2030 climate conditions (Project 2030 Scenario) and 2070 climate conditions (Project 2070 Scenario). The Project 2030 and 2070 Scenarios include three components: 1) in -lieu recharge, with recycled water deliveries replacing groundwater extraction; 2) wintertime irrigation utilizing recycled water to support groundwater replenishment; and, 3) extraction of stored water, using existing municipal groundwater wells. The Program proposes to serve up to 50,000 acre-feet per year (AFY) of recycled water for year-round agricultural use in the southern portion of Sacramento County.

Information is presented in five sections, as follows:

- Section 1, Modeling Approach, describes the modeling approach used in this analysis.
- Section 2, Baselines, describes the two climate baselines developed for this work.
- Section 3, Project Scenario Modeling, presents details on modeling of the proposed project under the two baselines.
- Section 4, Results, presents the modeling scenario results.
- Section 5, Summary, provides a summary of the model results.

Figures and tables are provided at the end of each section and Appendix A describes water year types used for this study.

Modeling results show the benefits of in-lieu and wintertime agricultural recharge of recycled water by the project. Initial benefits from recharge are accrued primarily to groundwater in storage, while later benefits are accrued primarily to surface water flow. The potential benefits from the program are to the groundwater storage, streamflows, riparian habitats, and water supply reliability during droughts.

1 Modeling Approach

Modeling was performed using the Sacramento Area Integrated Water Resources Model (SacIWRM), a comprehensive integrated hydrologic modeling environment that includes:

- Groundwater Flow Simulation
- Land & Water Use Analysis
- Soil Moisture Accounting
- Unsaturated Flow Simulation
- Surface Flow Simulation
- Stream-Aquifer Interaction
- Reservoir Operation
- Particle Tracking

The modeling analysis is based on the Future Conditions Baseline SacIWRM (FC Baseline), representing basin conditions assuming 2030 projections for land use, urban demand, and water supply conditions within the Central Basin of the modeling area.

SacIWRM was first developed based on the public domain and widely used Integrated Ground and Surface water Model (IGSM) code, which was born in a University of California Los Angeles (UCLA) Lab in 1976. SacIWRM has been continuously enhanced, modified, and used in the Sacramento region. Over the course of the past two decades, SacIWRM has been used in numerous studies and has supported various county-wide efforts since 1990s, for evaluating land and water use plans, water supply alternatives, conjunctive use options, water quality conditions, and other surface water and groundwater planning. The model has been maintained by various agencies responsible for the water resources planning and management in the Sacramento County area, and is a living model of the regional water resources conditions in the basin. The broad acceptance of the model across the community as the best available regional model for the area has allowed for the utilization of the model in numerous projects across the county. Refinements and updates are made to the model to meet the needs of each project, improving the model for future work, with the model calibrated to regional and local groundwater levels and streamflows.

The modeling analysis follows the WSIP guidelines as outlined by the California Water Commission (CWC) in the November 2, 2016 Draft Technical Reference document, which were adopted at the December 14, 2016 CWC meeting[1]. The modeling analysis uses two future climate change conditions as baselines to represent 2030 and 2070 climate change conditions. Hydrologic data (precipitation, evapotranspiration, and streamflow) were modified to represent the 2030 and 2070 climate change conditions in the project area. The 2030 and 2070 climate change conditions with and without the project were used to evaluate the potential impacts and benefits of the project scenario.

[1] https://cwc.ca.gov/Documents/2017/WSIP/TechnicalReference.pdf

2 Baselines

The modeling analysis included the update of the existing FC Baseline without the project to represent the land use and water use conditions projected in the year 2030. The FC Baseline utilizes the SacIWRM representing basin conditions assuming the general plan build-out, water use, and water supply conditions in the year 2030 in the project area. The 42-year hydrologic conditions of 1970-2011 were repeated two times to evaluate the long-term effects of water resources management activities on the basin.

Consistent with the WSIP guidelines, the 2030 Climate Change Baseline (2030 Climate Baseline) and 2070 Climate Change Baseline (2070 Climate Baseline), were developed using the FC Baseline but with the hydrologic data (precipitation, evapotranspiration, and streamflow) modified to represent the 2030 and 2070 climate change conditions without the project. The 2030 Climate Baseline and 2070 Climate Baseline were used to allow for the analysis of impacts and benefits of the project scenario under the 2030 and 2070 climate conditions for the WSIP guidelines. These two climate change baselines provide a basis for comparison so that the project impacts and benefits can be evaluated with the 2030 and 2070 climate conditions by isolating changes that may occur in the basin.

2.1 2030 Baseline

To meet the requirements of the WSIP, the FC Baseline was first updated to represent the land use and water use conditions projected at 2030 based on the information available from the 2015 Urban Water Management Plans and the latest general plans. This update mainly focused on the Central portion of the basin where the project is located and where it would have the most impacts on the project area. The current version of the SacIWRM covers the greater Sacramento region. The Sutter County and western Placer County portions of the SacIWRM were considered too distant to have significant impacts on conditions in the project area; therefore, no modifications to water demand and supply projections were made in those areas.

2.2 2030 and 2070 Climate Baselines

The 2030 and 2070 Climate Baselines were developed using the updated FC Baseline at 2030 conditions with modified hydrologic data (precipitation, evapotranspiration, and streamflow) to incorporate the 2030 and 2070 climate change conditions. Perturbation approach was used to modify precipitation and evapotranspiration with climate change following the methodology and data available from the CWC based on grid cell data[2]. Data from climate change scenarios for CalSim-II were acquired and used to develop perturbation factors for the major rivers in the model area. The hydrologic data were modified by applying a fractional change, or perturbation, based on the changes estimated from the CWC grid cell data. The fractional changes, or the ratios, were calculated based on grid cell data from the CWC between the historical data (de-trended) and 2030 and 2070 climate change conditions. These ratios were applied to every month

[2] Climate change and sea level rise data and model outputs provided by CWC in the WSIP Application Resources website (https://cwc.ca.gov/Pages/ApplicationResources.aspx), including model results without-project 2030 future conditions (https://d3.water.ca.gov/owncloud/index.php/s/EFQAKMLgR1cdE9R/download) and without-project 2070 future conditions https://d3.water.ca.gov/owncloud/index.php/s/QHPV35poJBlQybF/download).

to generate the climate change data for the 2030 and 2070 climate conditions. For daily hydrologic data in the model (precipitation and streamflows), the fractions were assumed to remain constant in a given month. For evapotranspiration, monthly average ratios calculated based on grid cell data from the CWC were used to modify the monthly evapotranspiration for the 2030 and 2070 climate conditions. The modification to the hydrologic data for climate change covered the Sacramento County portion of the SacIWRM. Perturbation factors, or the ratios, were developed for creeks and streams not simulated in CalSim-II using precipitation grid cell data developed by the CWC for the climate change conditions. The SacIWRM also uses the modified hydrologic climate data to update ungauged small watersheds[3] to reflect the climate change conditions.

Land use and water use conditions were assumed at 2030 levels and do not incorporate adaptation to climate change conditions in a manner to reduce climate impacts. This approach is consistent with CalSim-II simulations available by the CWC for the climate change analysis that represent how the current system would respond to climate change, but do not incorporate future climate change adaptation that may require management of the system in a manner different from today to reduce climate impacts. The SacIWRM simulates changes in agricultural water demand as a result of changes to the hydrologic data from climate change for 2030 and 2070 conditions, but changes to the system operations, potential changes to land use (crop acreage and urbanization), and resulting changes in urban water demands on the system are currently unknown as a result of climate change; thus, these changes are not incorporated in the SacIWRM modeling.

2.2.1 2030 Climate Baseline

To show the status of the basins under the assumed future conditions and to document this comparison point used with the project scenario, the results of the 2030 Climate Baseline modeling are shown in the following figures:

- Groundwater hydrographs at five locations, shown on Figure 1~~Figure 1~~
  - Hydrograph for Location 1: Figure 2~~Figure 2~~
  - Hydrograph for Location 2: Figure 3~~Figure 3~~
  - Hydrograph for Location 3: Figure 4~~Figure 4~~
  - Hydrograph for Location 4: Figure 5~~Figure 5~~
  - Hydrograph for Location 5: Figure 6~~Figure 6~~
- Groundwater elevation maps for three selected dates, representing different hydrologic conditions
  - Wet (fall 1984): Figure 7~~Figure 7~~
  - Dry (fall 1994): Figure 8~~Figure 8~~
  - Normal (fall 2004): Figure 9~~Figure 9~~

[3] The small watersheds simulated by the SacIWRM include: Coon Creek, Doly Ravine, Auburn Canal, Dry Creek (North), Canson Creek, Jackson Creek, Deer Creek, Arkansas Creek, Willow Creek, Dry Creek (South), Sutter Creek, and a couple of unnamed creeks.

- Depth to groundwater maps for three selected dates, representing different hydrologic conditions
  - Wet (fall 1984): Figure 10~~Figure 10~~
  - Dry (fall 1994): Figure 11~~Figure 11~~
  - Normal (fall 2004): Figure 12~~Figure 12~~
- Percent of time groundwater levels are within 25 feet of the ground surface: Figure 13~~Figure 13~~
- Streamflow hydrographs at two locations, shown on Figure 1~~Figure 1~~
  - Cosumnes River at Highway 99 (McConnell gage): Figure 14~~Figure 14~~
  - Cosumnes River at Twin Cities Road: Figure 15~~Figure 15~~

These results suggest an area with a groundwater system heavily influenced by two factors: extensive recharge from rivers, notably the Cosumnes River, and local and regional groundwater extraction for urban and agricultural use. The surface water system is impacted by groundwater withdrawals. Flows in the Cosumnes River are low for much of the summer, fall, and early winter. The flows are, however, higher than the conditions seen in the area currently due to the assumptions incorporated into the 2030 Climate Baseline, including extensive surface water deliveries into Sacramento County Water Agency's (SCWA) delivery area in southeastern Sacramento County from the Vineyard Surface Water Treatment Plant. These levels under future water and land use conditions, however, remain inadequate to meet the levels of streamflow and riparian habitat desired by environmental organizations and many in the community. Project results in Section 4.1 can be compared to the percent of time groundwater levels are within 25 feet of the ground surface and to streamflow hydrographs to quantify project benefits in these areas. Twenty-five feet was selected in coordination with staff from The Nature Conservancy as a metric for riparian health.

Figures and Tables: 2030 Climate Baseline

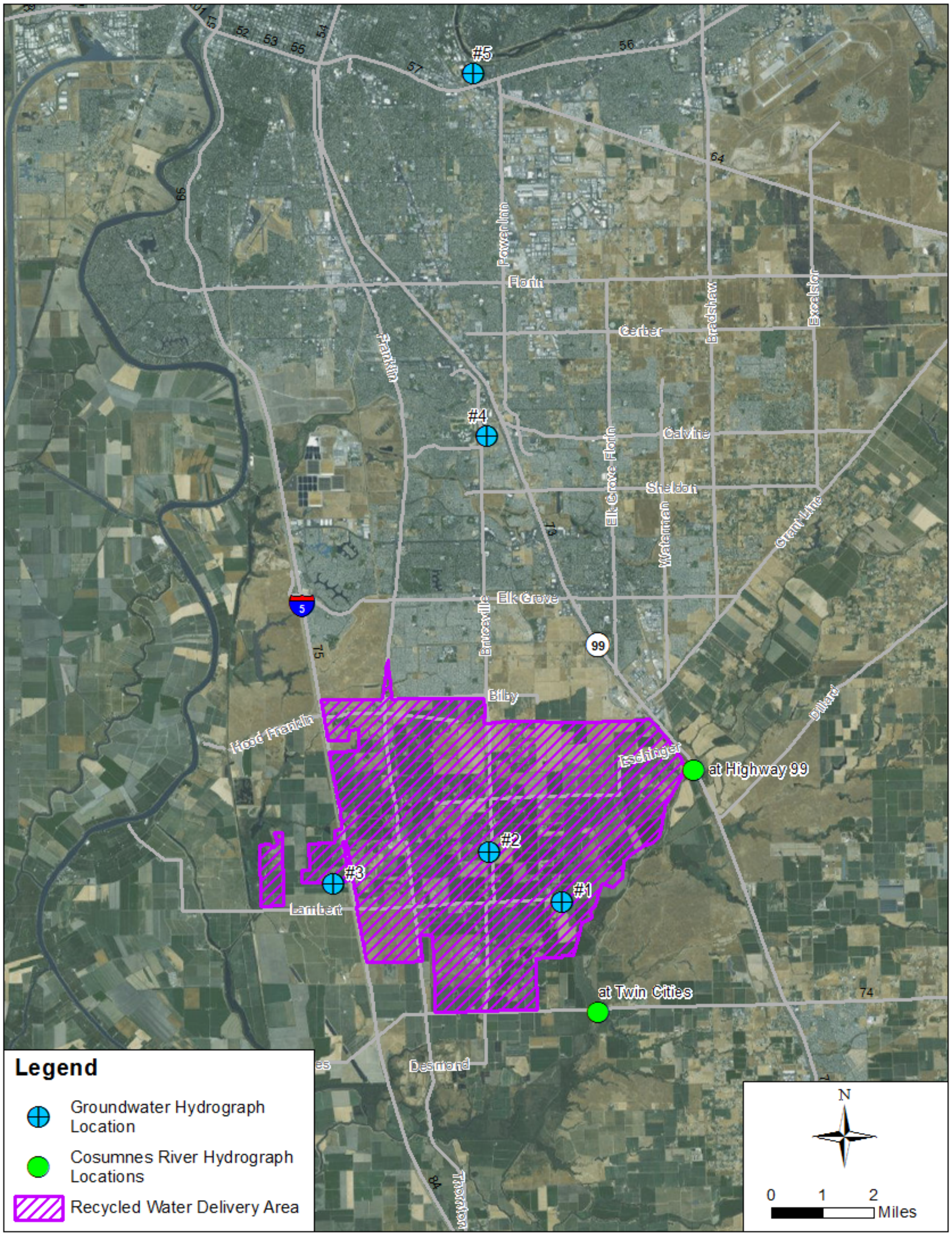


Figure 1: Project In-Lieu Service Area and SacIWRM Groundwater Hydrograph Output Locations

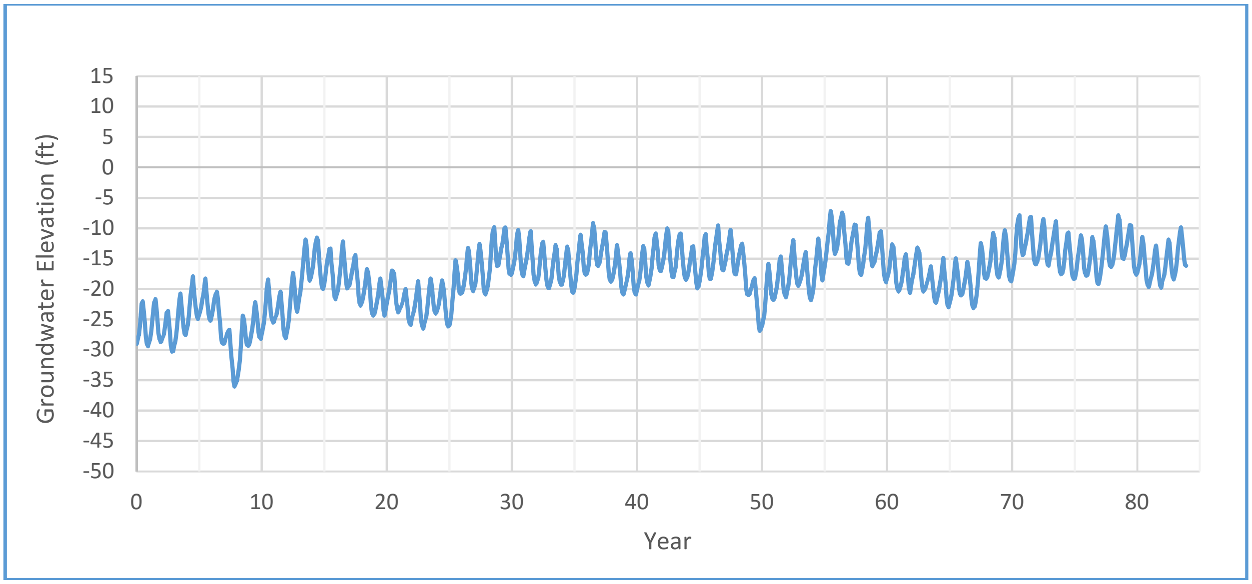


Figure 2: Groundwater Hydrograph at Location 1, 2030 Climate Baseline

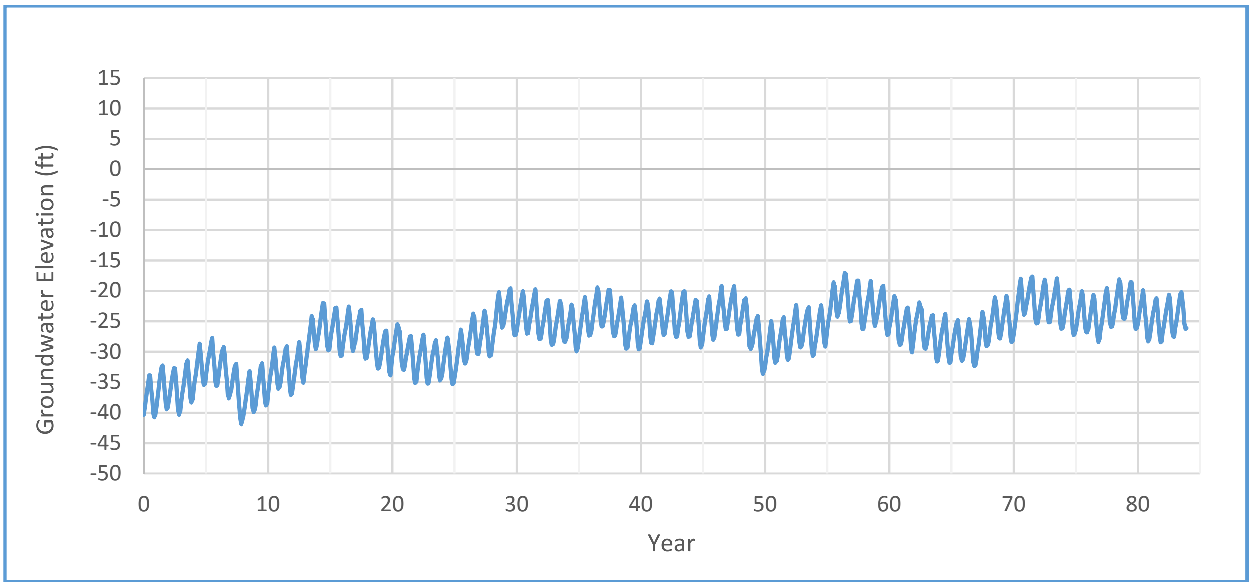


Figure 3: Groundwater Hydrograph at Location 2, 2030 Climate Baseline

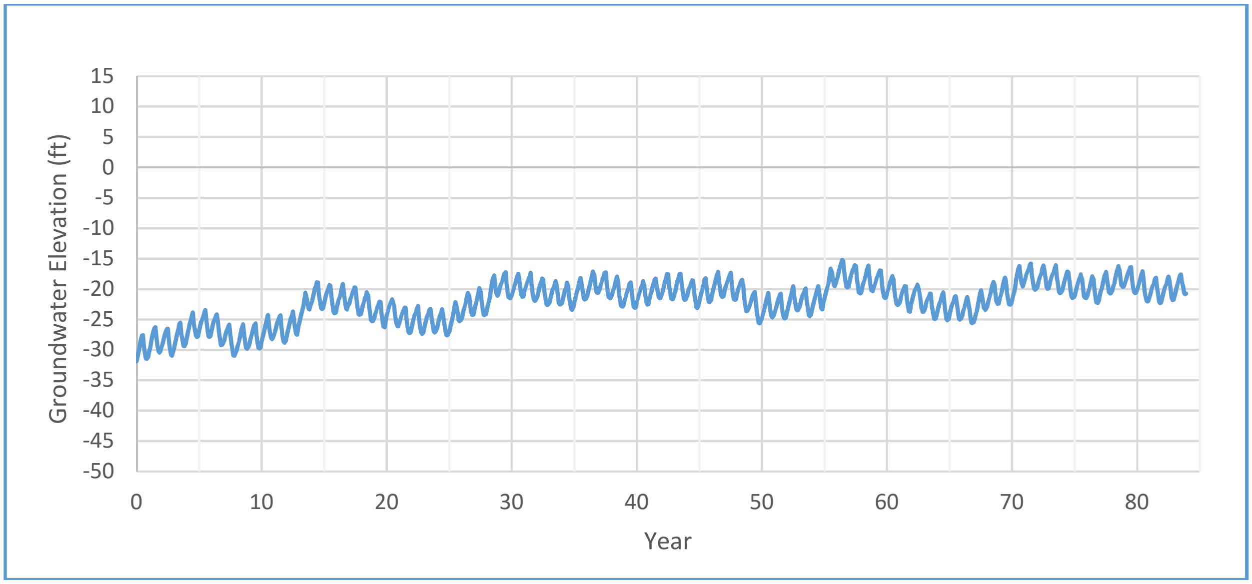


Figure 4: Groundwater Hydrograph at Location 3, 2030 Climate Baseline

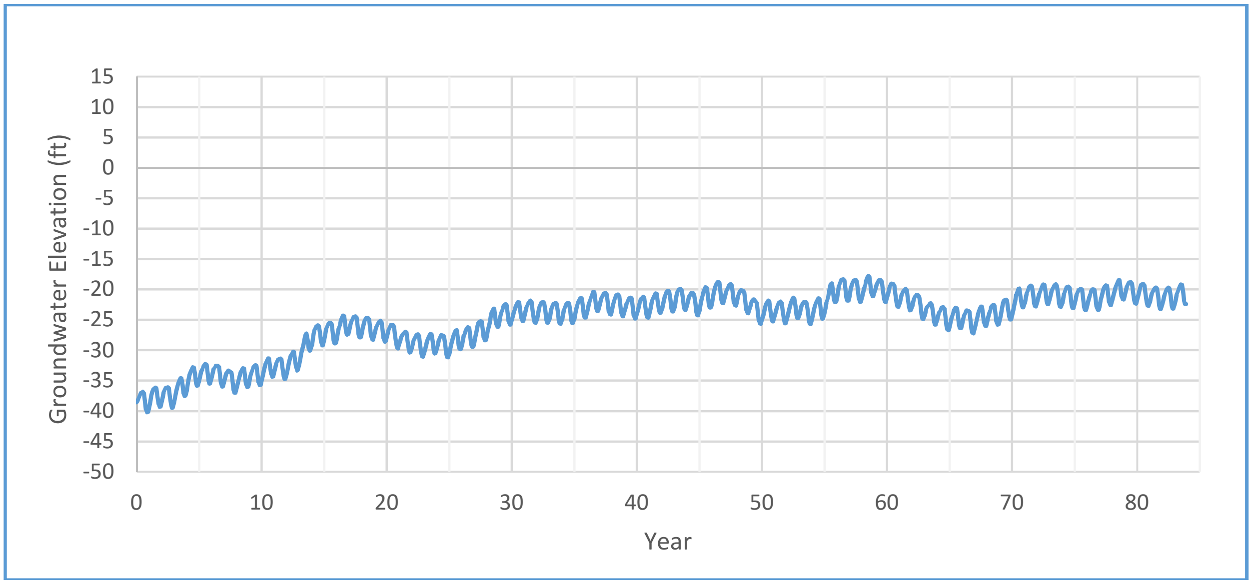


Figure 5: Groundwater Hydrograph at Location 4, 2030 Climate Baseline

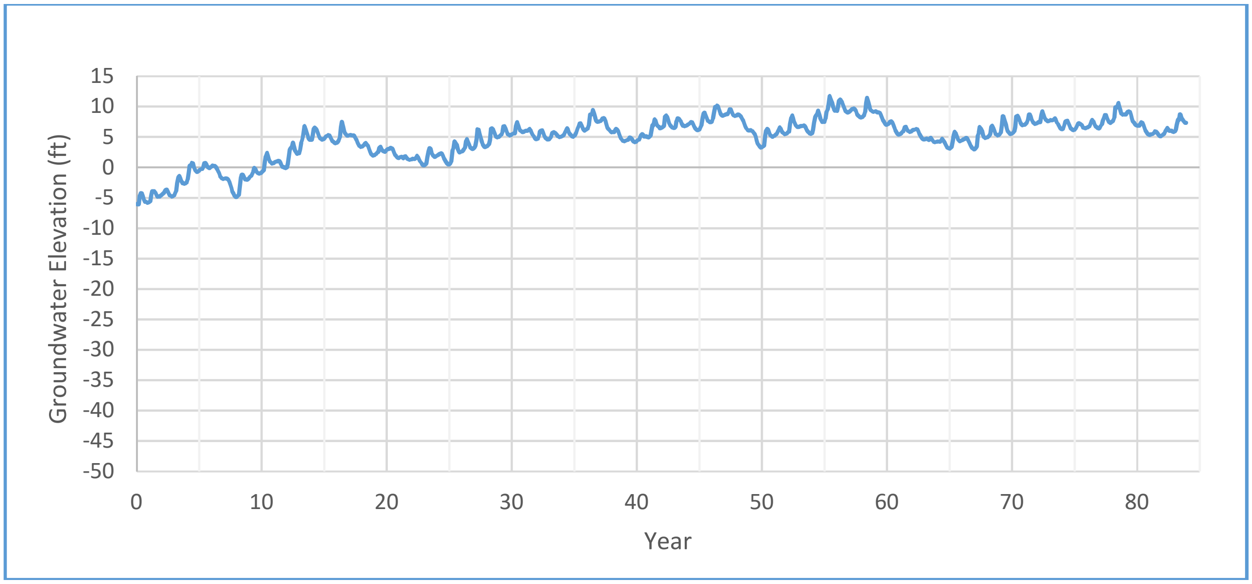


Figure 6: Groundwater Hydrograph at Location 5, 2030 Climate Baseline

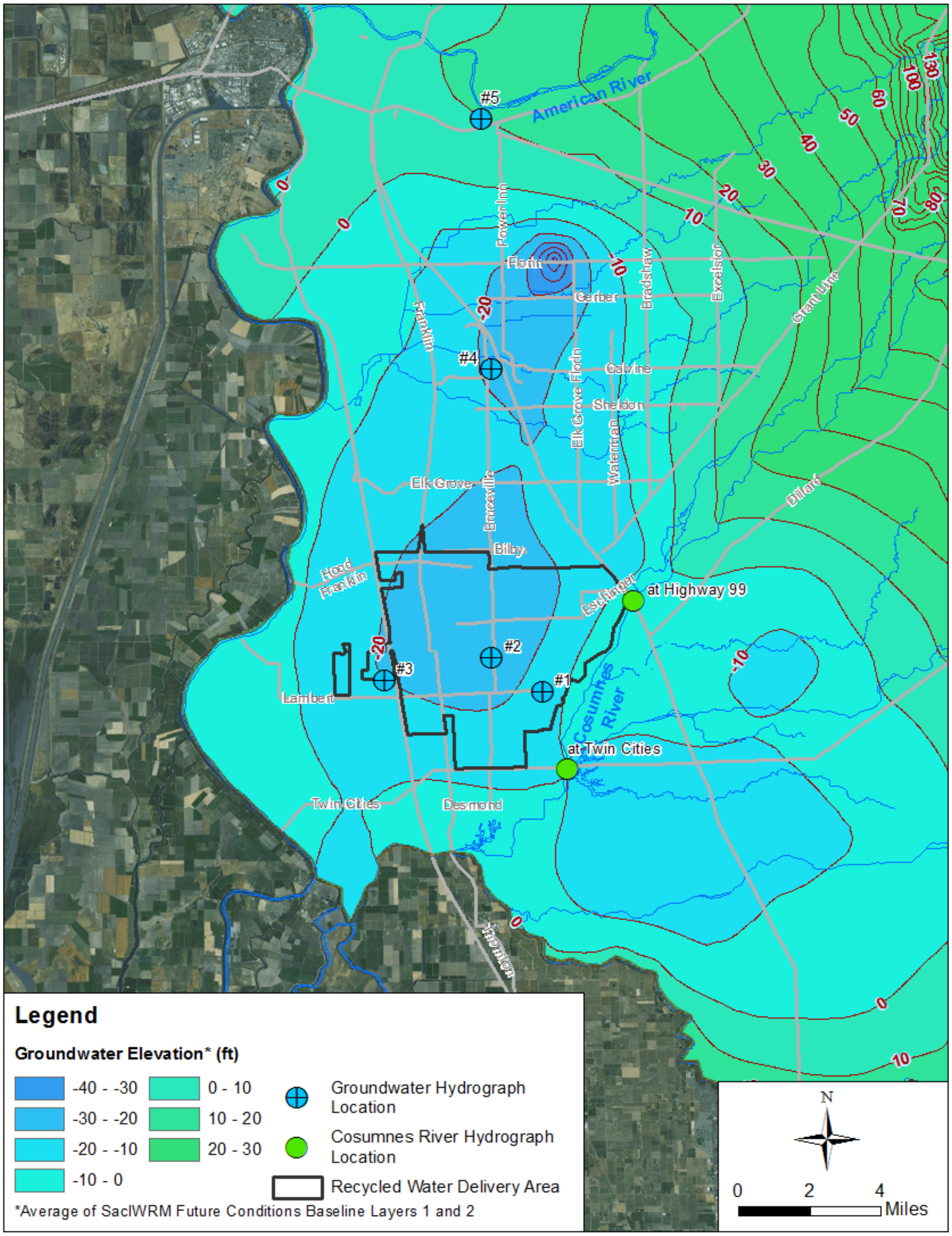


Figure 7: Groundwater Elevations, Wet Year (Fall 1984, 57th Year of Simulation), 2030 Climate Baseline

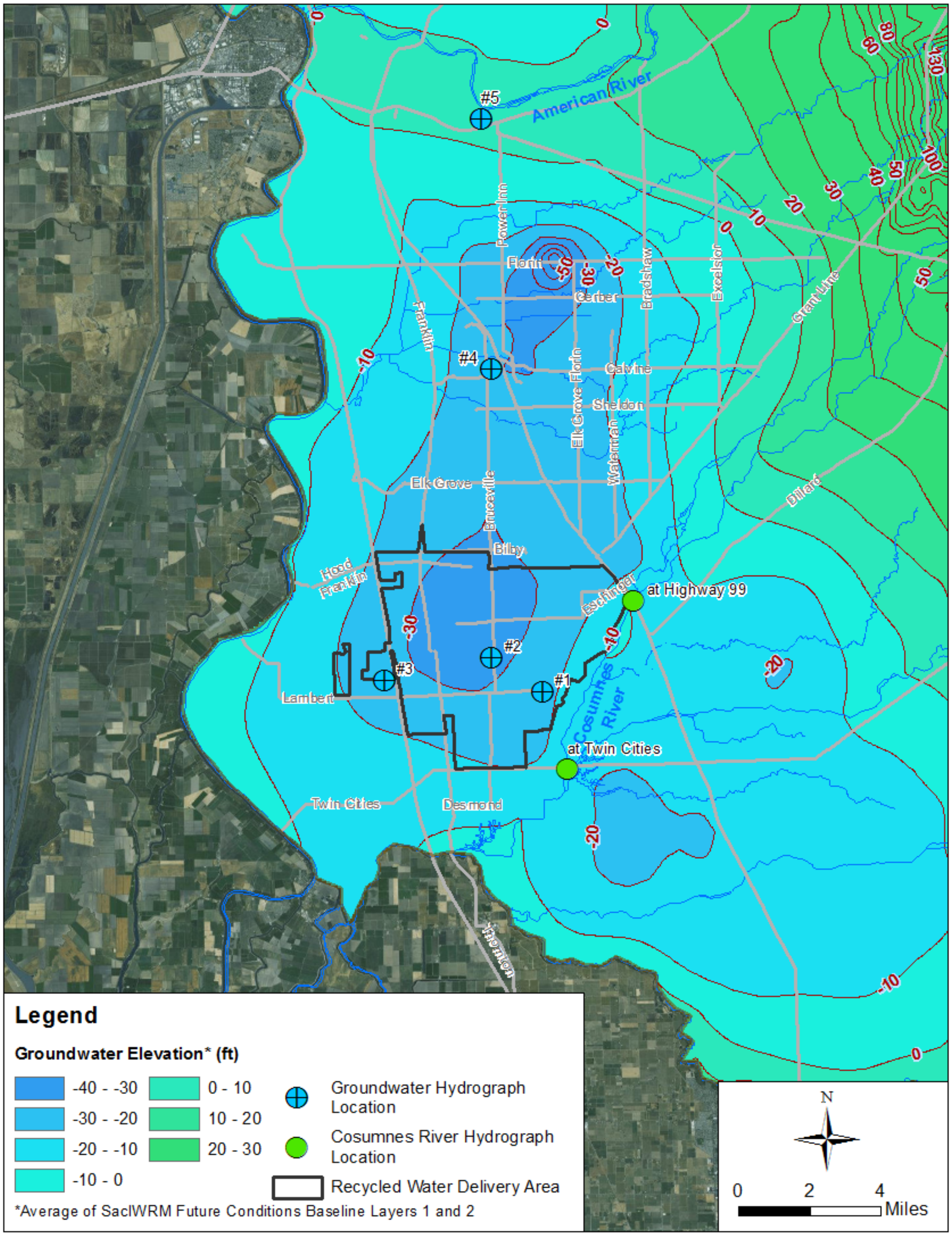


Figure 8: Groundwater Elevation, Dry Year (Fall 1994, 67th Year of Simulation), 2030 Climate Baseline

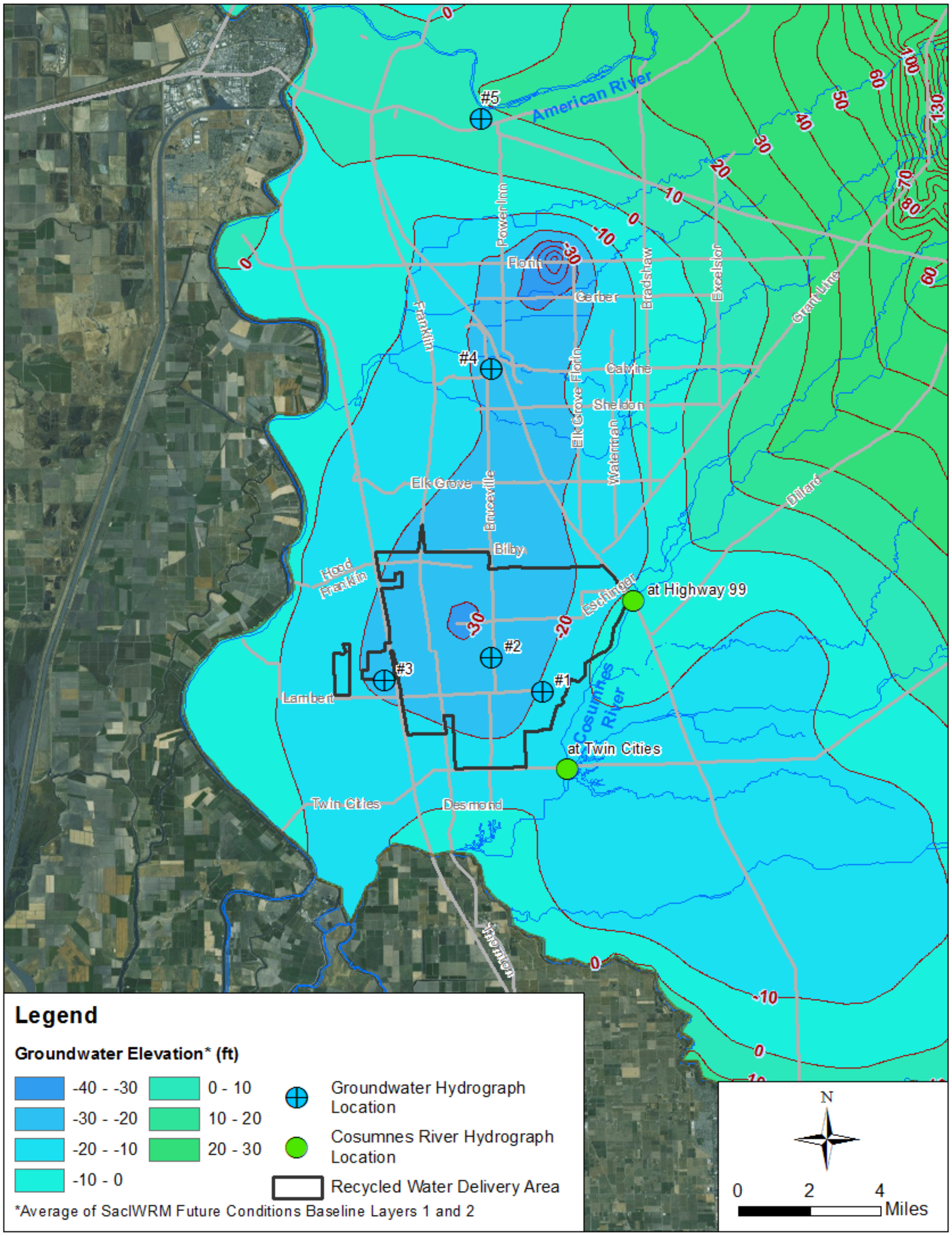


Figure 9: Groundwater Elevation, Normal Year (Fall 2004, 77th Year of Simulation), 2030 Climate Baseline

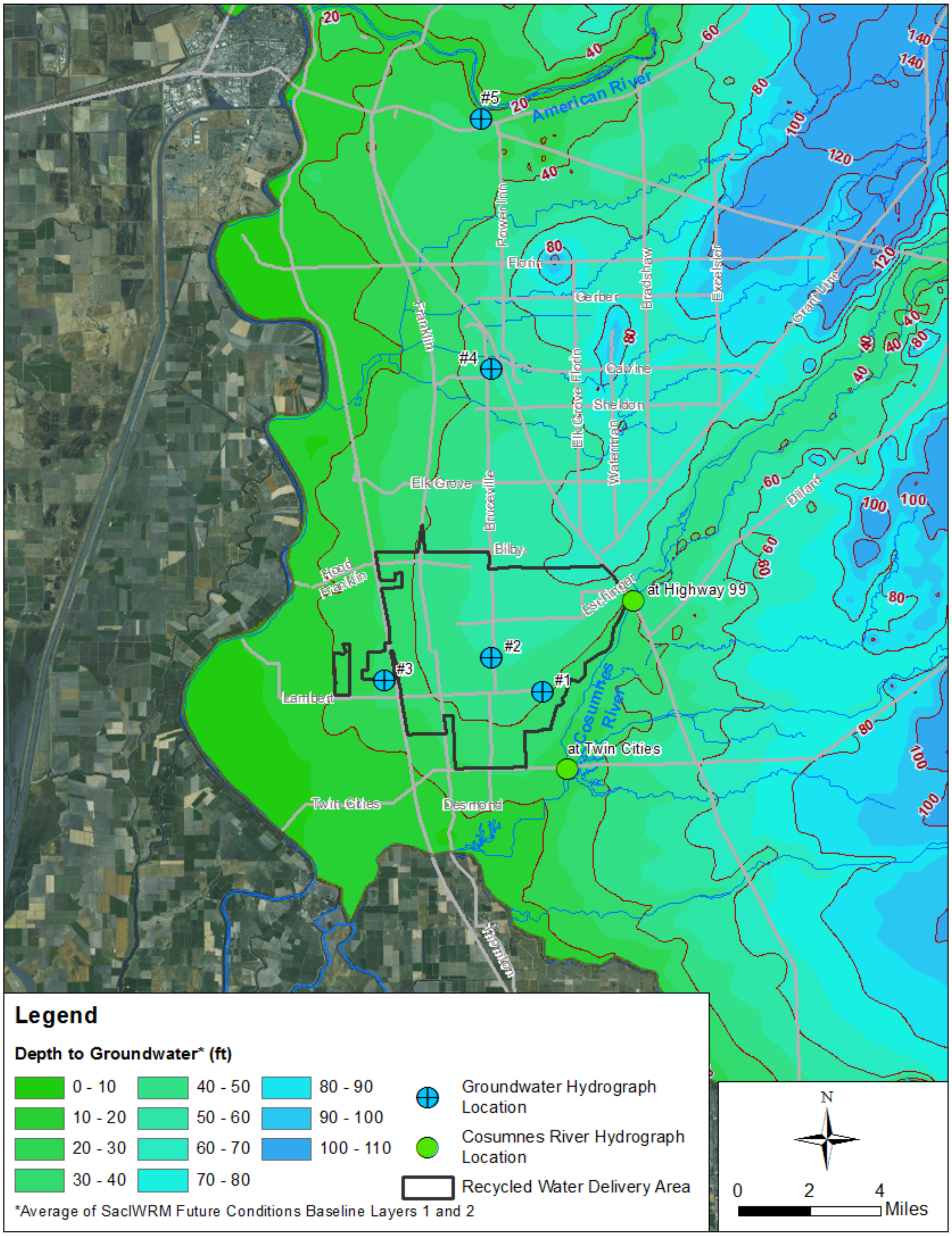


Figure 10: Depth to Groundwater, Wet Year (Fall 1984, 57th Year of Simulation), 2030 Climate Baseline

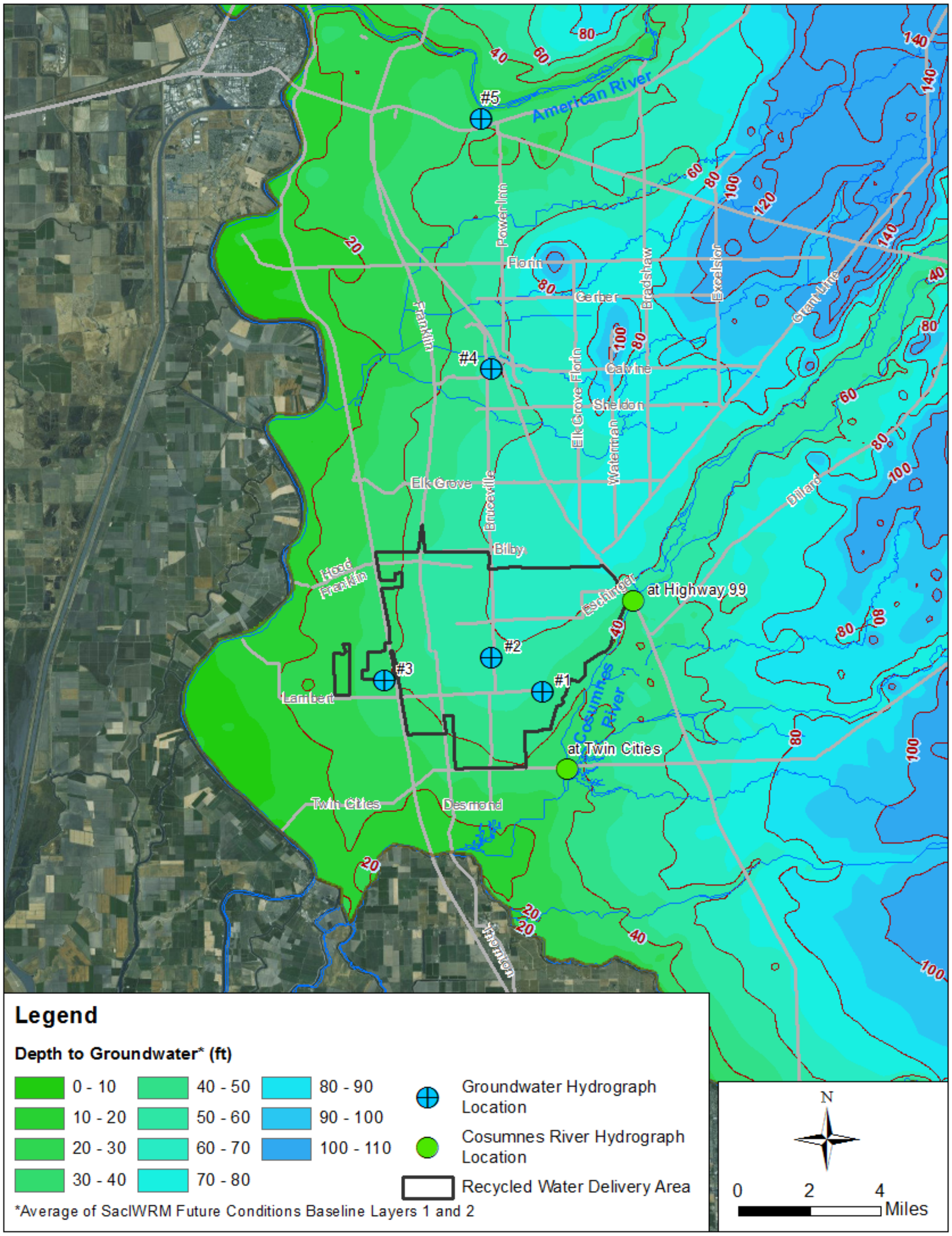


Figure 11: Depth to Groundwater, Dry Year (Fall 1994, 67th Year of Simulation), 2030 Climate Baseline

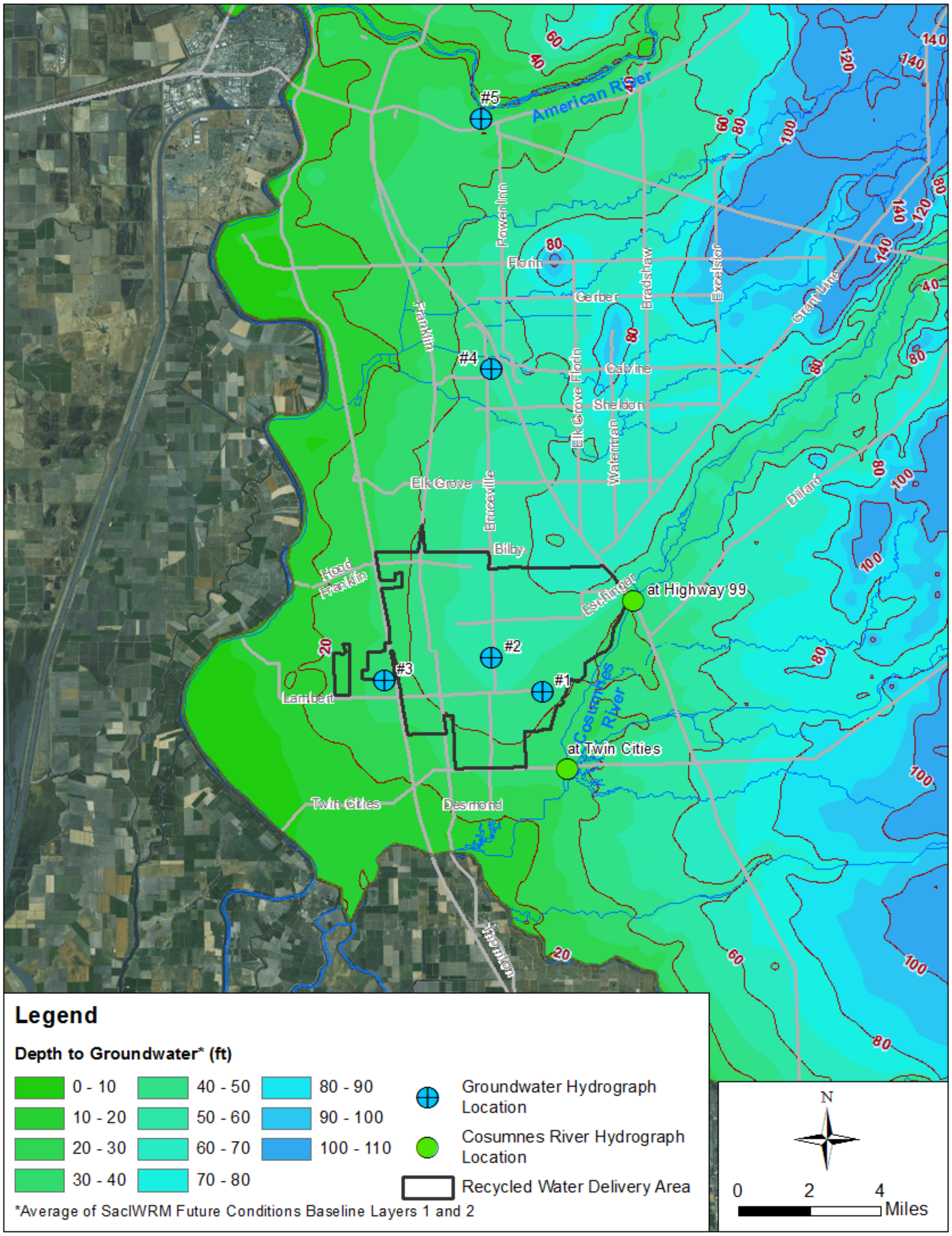
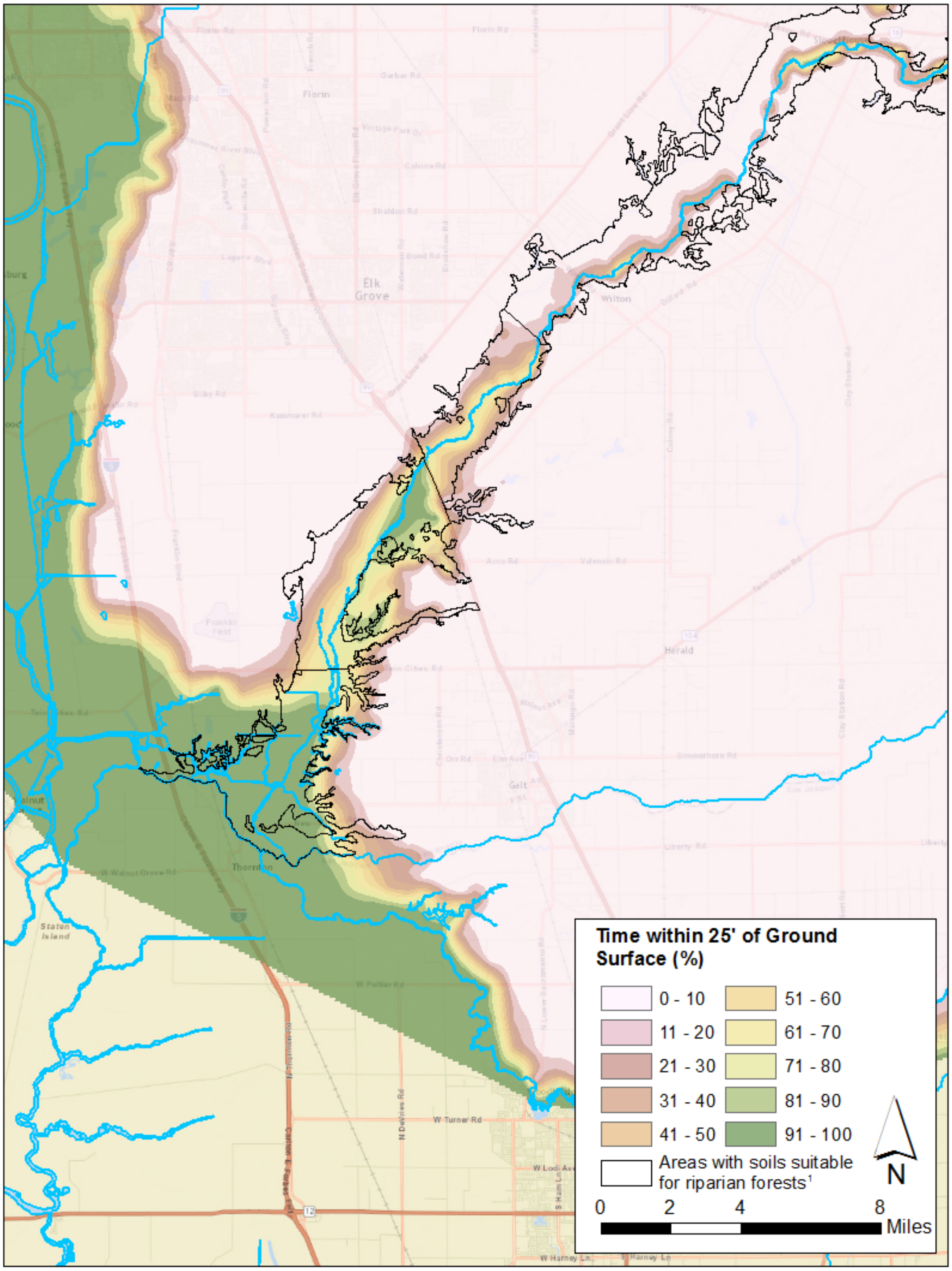


Figure 12: Depth to Groundwater, Normal Year (Fall 2004, 77th Year of Simulation), 2030 Climate Baseline



1. Source TNC 2014

Figure 13: Percent of Time Groundwater Levels are within 25 feet of the Ground Surface, 2030 Climate Baseline

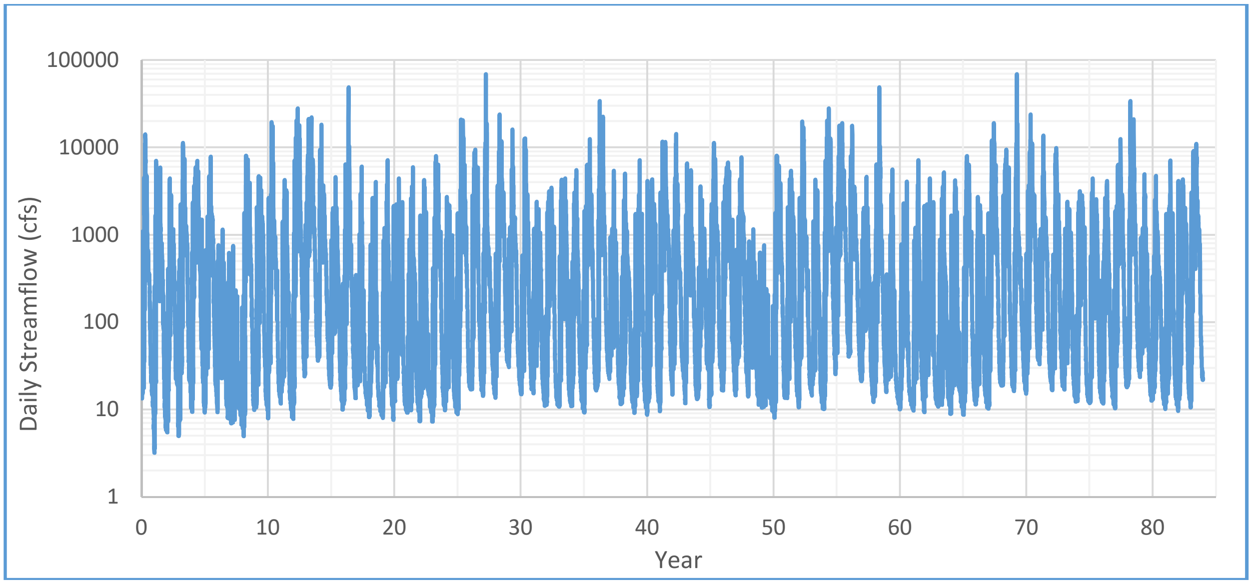


Figure 14: Streamflow Hydrograph at Cosumnes River at Highway 99 (McConnell Gage), 2030 Climate Baseline

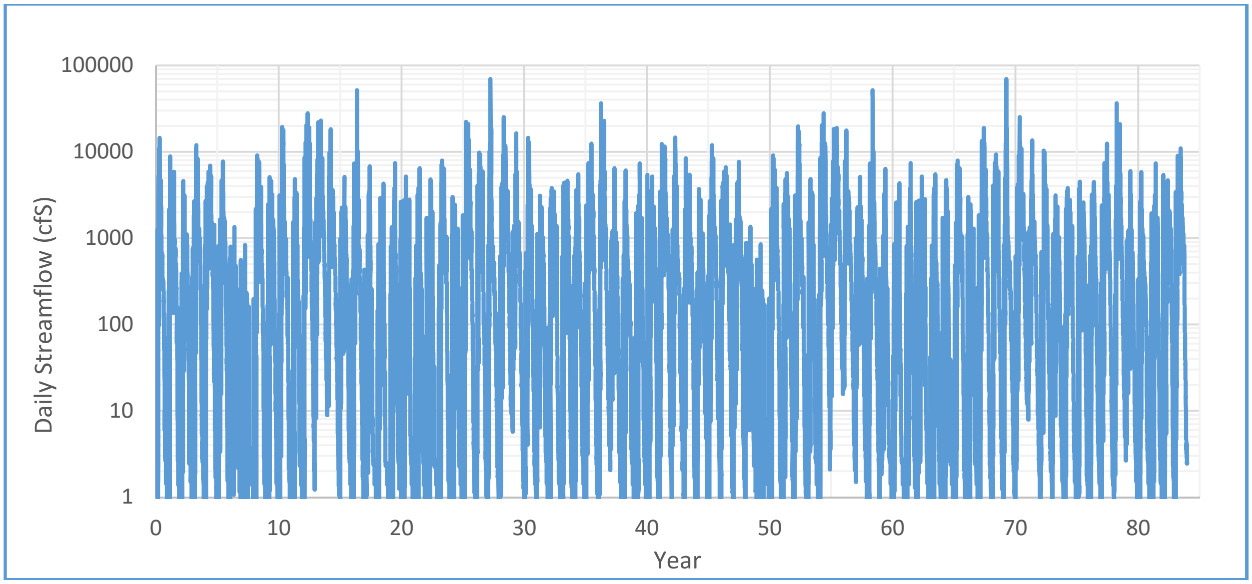


Figure 15: Streamflow Hydrograph at Cosumnes River at Twin Cities Road, 2030 Climate Baseline

2.3 2070 Climate Baseline

To show the status of the basins under the assumed future conditions and to document this comparison point used with the project scenario, the results of the 2070 Climate Baseline modeling are shown in the following figures:

- Groundwater hydrographs at five locations, shown on Figure 16~~Figure 16~~
    - Hydrograph for Location 1: Figure 17~~Figure 17~~
    - Hydrograph for Location 2: Figure 18~~Figure 18~~
    - Hydrograph for Location 3: Figure 19~~Figure 19~~
    - Hydrograph for Location 3: Figure 20~~Figure 20~~
    - Hydrograph for Location 3: Figure 21~~Figure 21~~
- Groundwater elevation maps for three selected dates, representing different hydrologic conditions
    - Wet (fall 1984): Figure 22~~Figure 22~~
    - Dry (fall 1994): Figure 23~~Figure 23~~
    - Normal (fall 2004): Figure 24~~Figure 24~~
- Depth to groundwater maps for three selected dates, representing different hydrologic conditions
    - Wet (fall 1984): Figure 25~~Figure 25~~
    - Dry (fall 1994): Figure 26~~Figure 26~~
    - Normal (fall 2004): Figure 27~~Figure 27~~
- Percent of time groundwater levels are within 25 feet of the ground surface: Figure 28~~Figure 28~~
- Streamflow hydrographs at two locations, shown on Figure 16~~Figure 16~~
    - Cosumnes River at Highway 99 (McConnell gage): Figure 29~~Figure 29~~
    - Cosumnes River at Twin Cities Road: Figure 30~~Figure 30~~

These results suggest an area with a groundwater system heavily influenced by two factors: extensive recharge from rivers, notably the Cosumnes River, and local and regional groundwater extraction for urban and agricultural use. Groundwater hydrographs suggest lower groundwater elevations compared to the 2030 climate conditions. As the simulation elapses, groundwater levels appear to remain stable over the course of the simulation period, as opposed to slightly increasing trends seen under the 2030 climate conditions. Groundwater elevation contour maps also consistently show lower groundwater levels within the project area and surrounding areas under the 2070 Climate Baseline compared to the 2030 Climate Baseline. The lowest levels are generally observed during dry hydrologic conditions (Figure 23~~Figure 23~~). This is attributed to increased agricultural demand in response to the 2070 climate conditions and resulting increased pumping to meet that demand.

The surface water system is impacted by groundwater withdrawals. Flows in the Cosumnes River are low for much of the summer, fall, and early winter. The flows are, however, higher than the conditions seen in the area currently due to the assumptions incorporated into the Baseline, including extensive surface water deliveries into SCWA's delivery area in southeastern Sacramento County from the Vineyard Surface Water Treatment Plant. These levels under future water and land use conditions, however, remain inadequate to meet the levels of streamflow and riparian habitat desired by environmental organizations and many in the community. Project results in Section 4.2 can be compared to the percent of time groundwater levels are within 25 feet of the ground surface and to streamflow hydrographs to quantify project benefits in these areas. Twenty-five feet was selected in coordination with staff from The Nature Conservancy as a metric for riparian health.

Figures and Tables: 2070 Climate Baseline

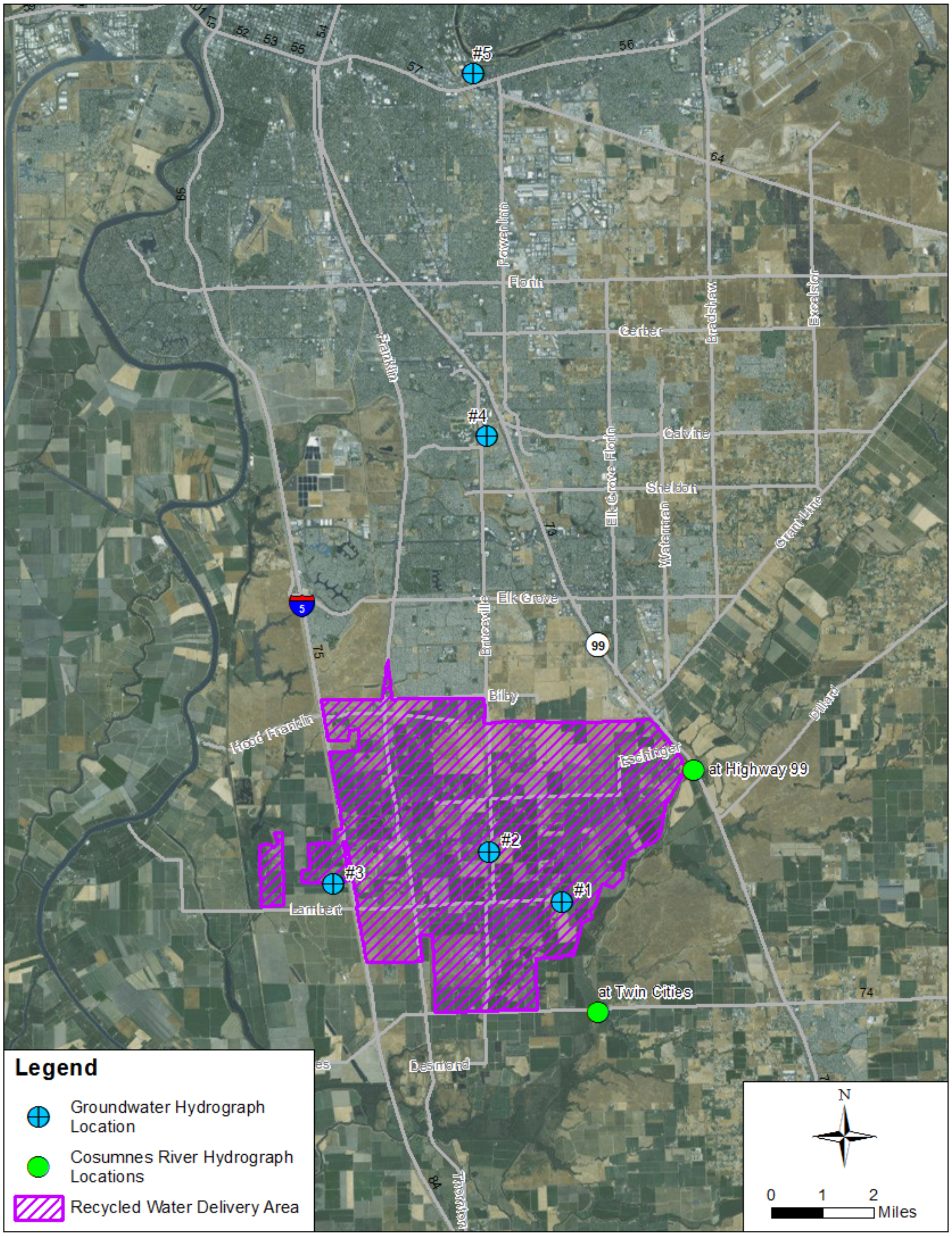


Figure 16: Project In-Lieu Service Area and SacIWRM Groundwater Hydrograph Output Locations

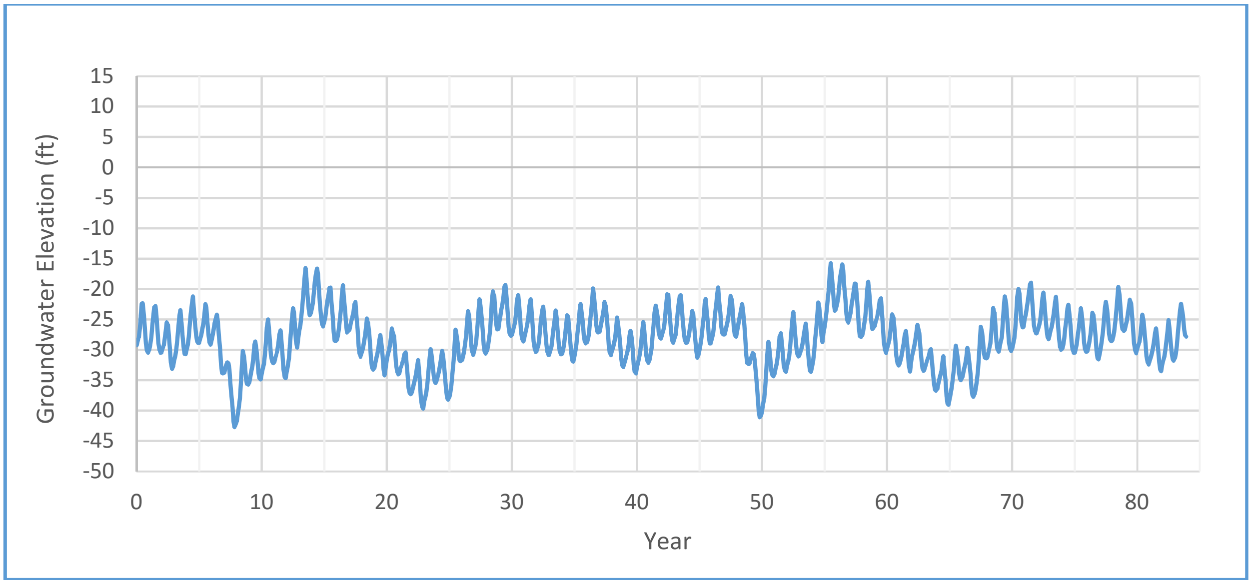


Figure 17: Groundwater Hydrograph at Location 1, 2070 Climate Baseline

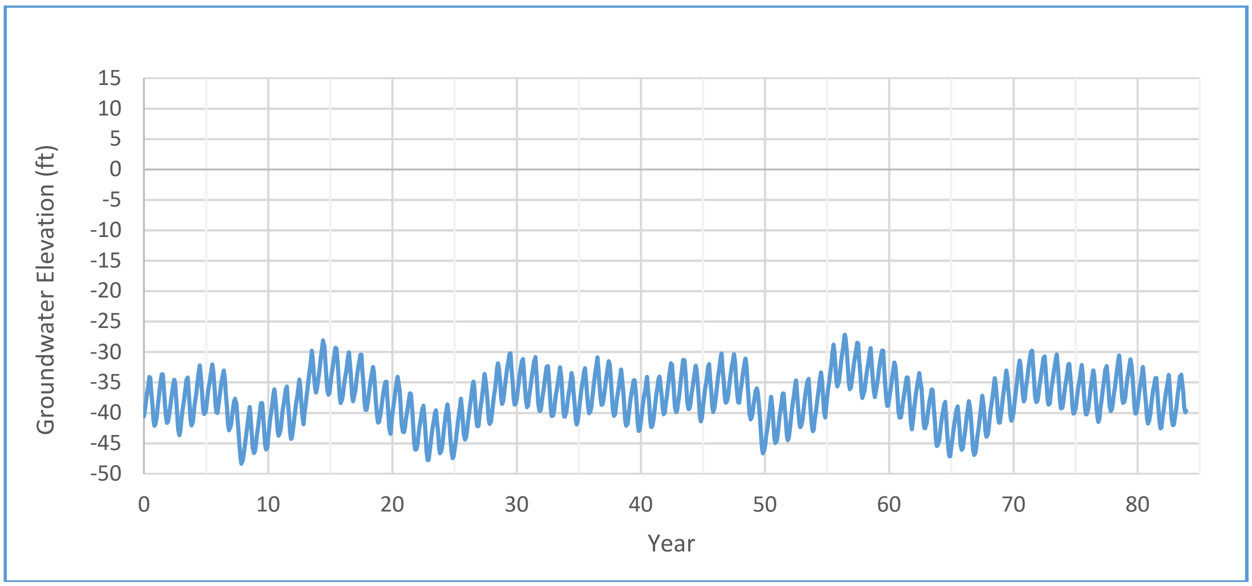


Figure 18: Groundwater Hydrograph at Location 2, 2070 Climate Baseline

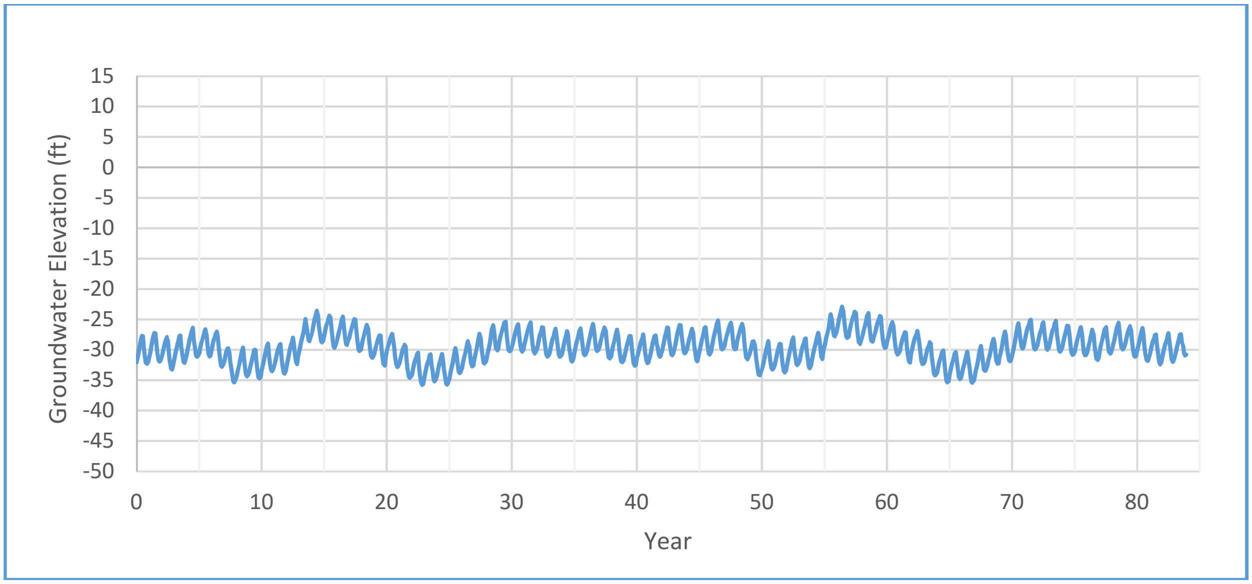


Figure 19: Groundwater Hydrograph at Location 3, 2070 Climate Baseline

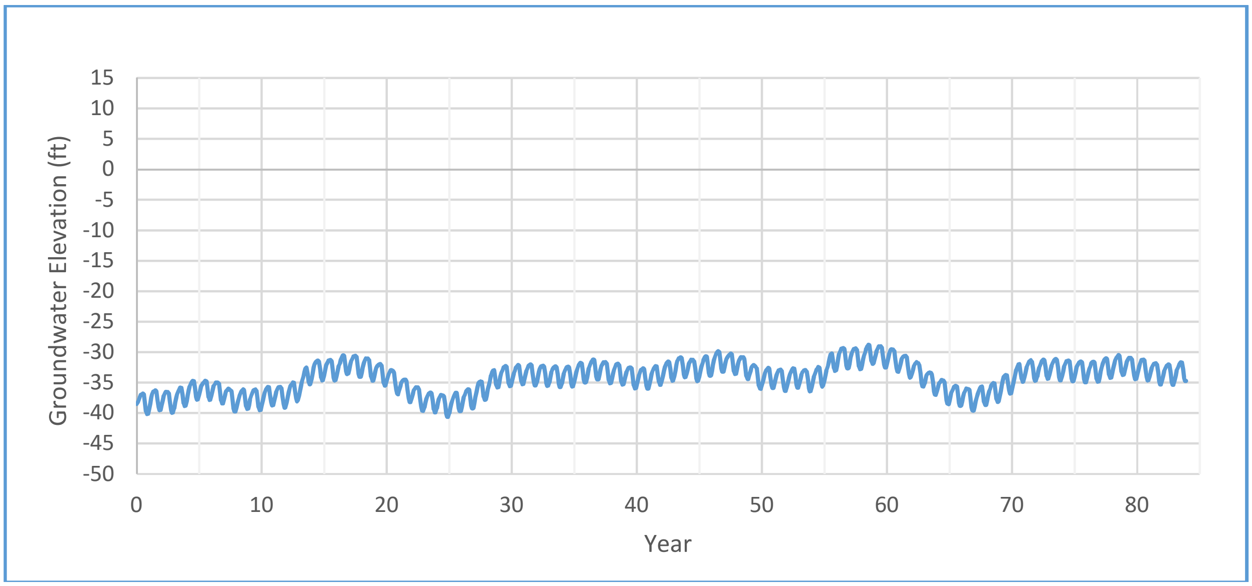


Figure 20: Groundwater Hydrograph at Location 4, 2070 Climate Baseline

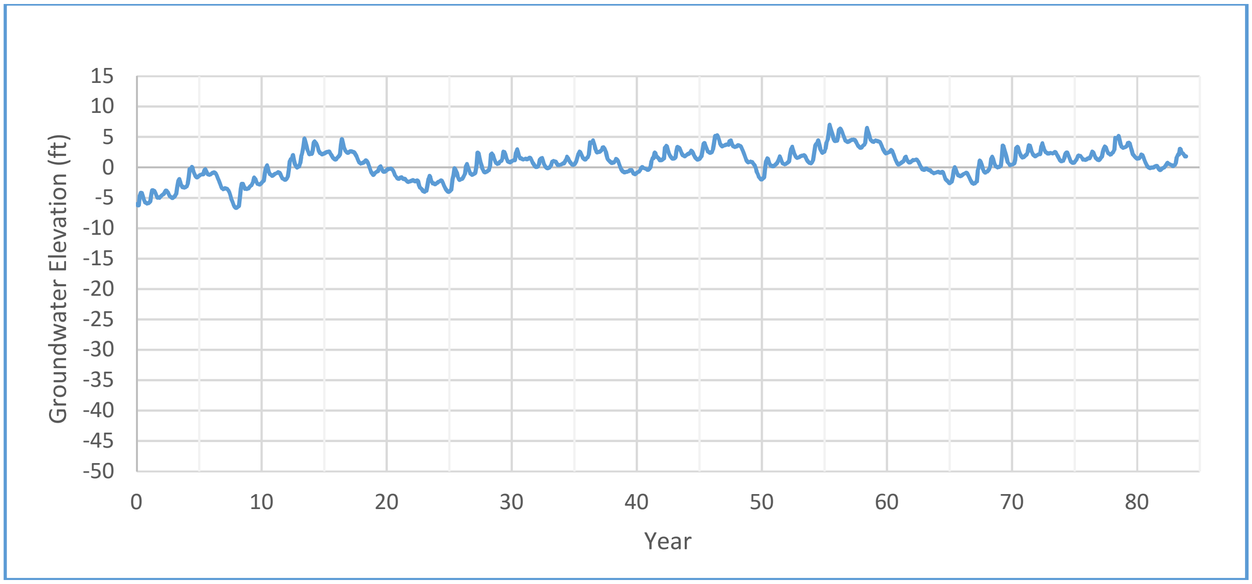


Figure 21: Groundwater Hydrograph at Location 5, 2070 Climate Baseline

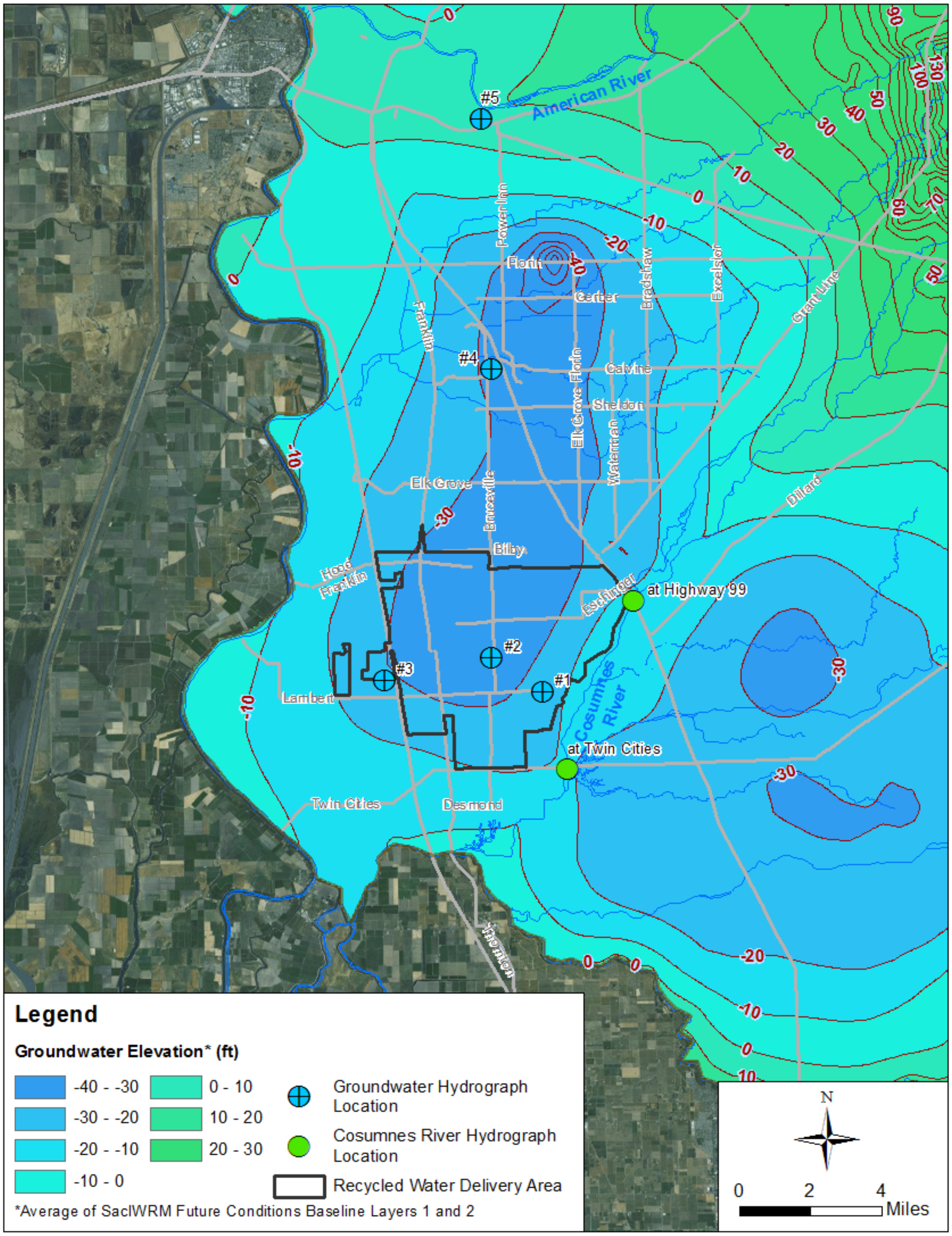


Figure 22: Groundwater Elevations, Wet Year (Fall 1984, 57th Year of Simulation), 2070 Climate Baseline

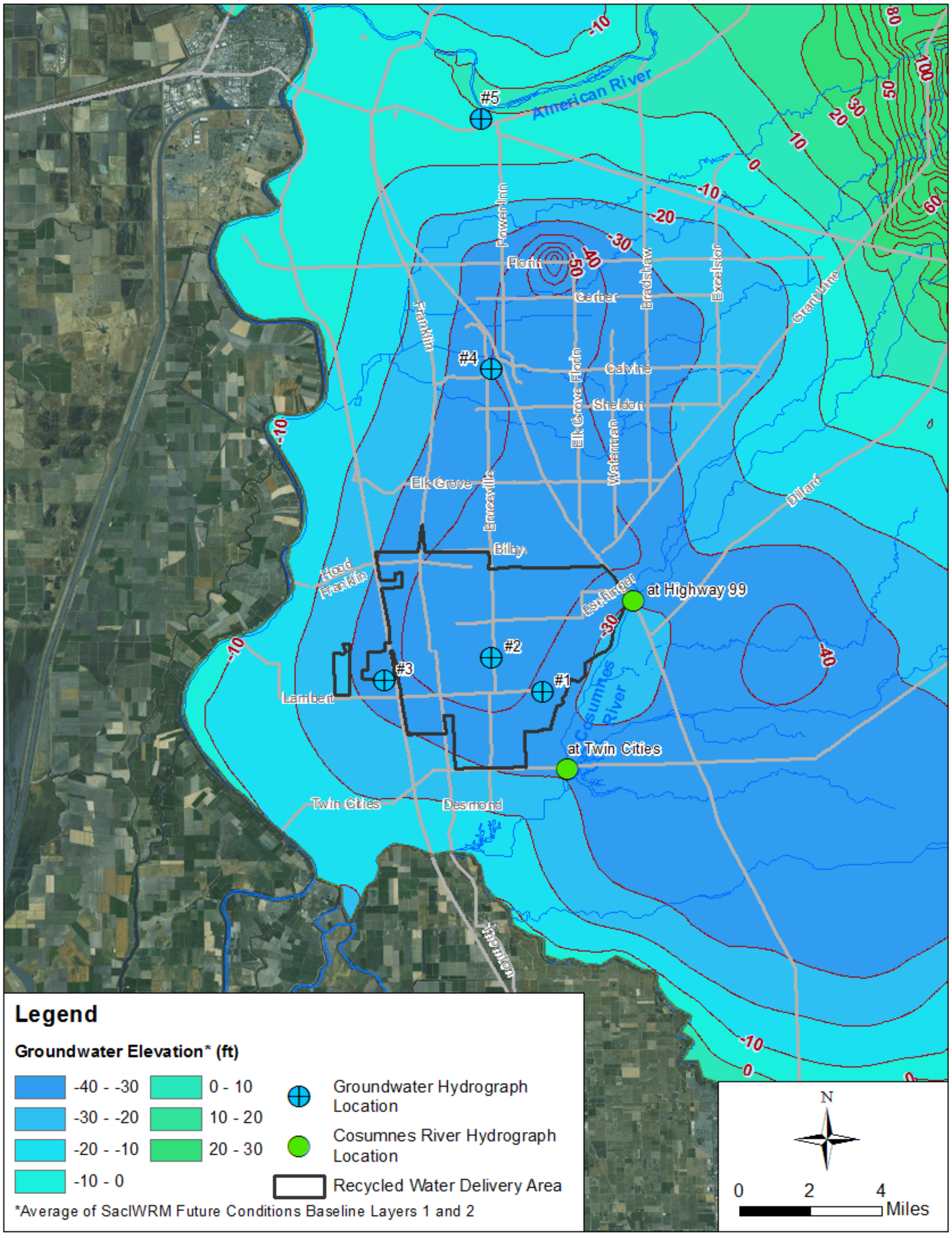


Figure 23: Groundwater Elevation, Dry Year (Fall 1994, 67th Year of Simulation), 2070 Climate Baseline

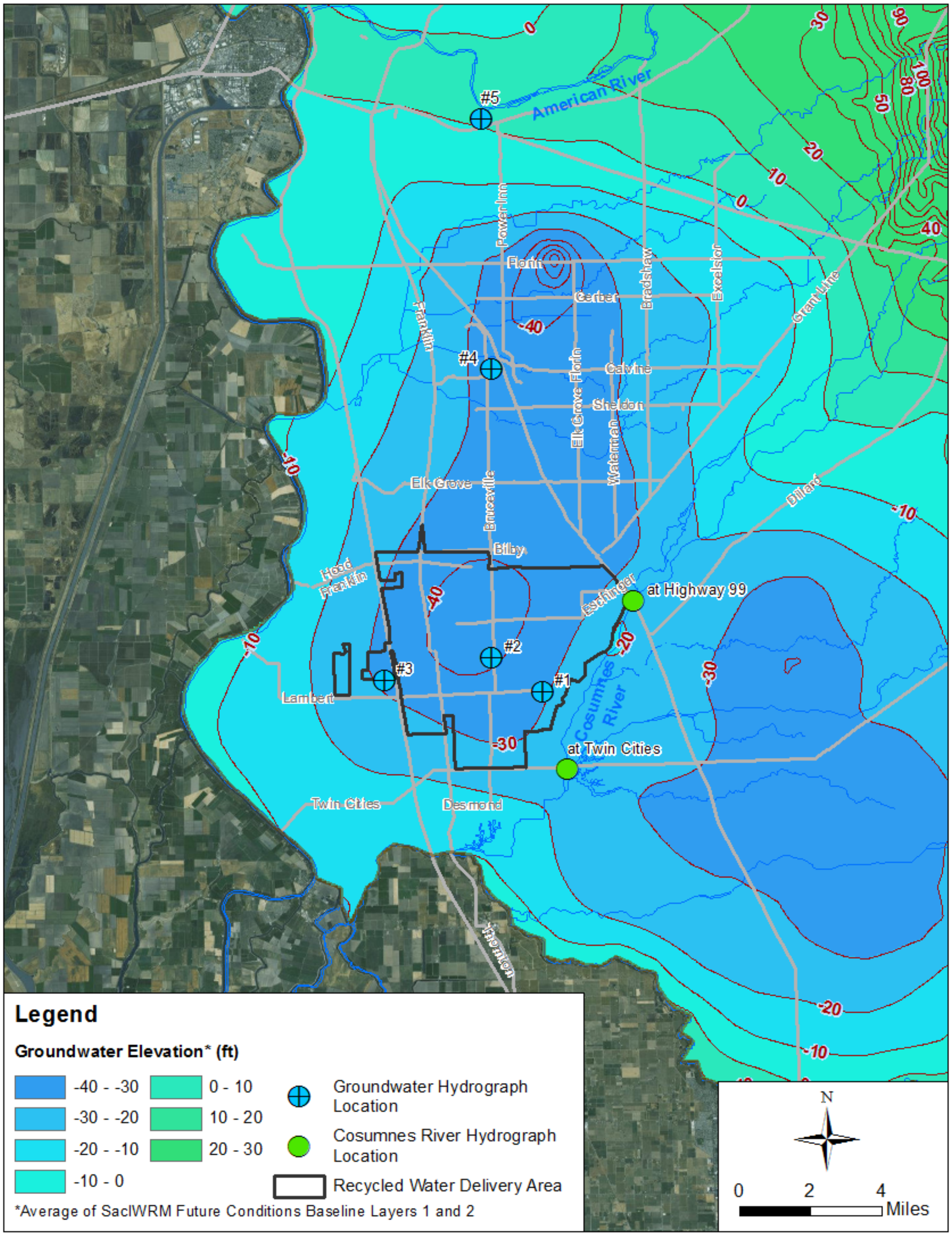


Figure 24: Groundwater Elevation, Normal Year (Fall 2004, 77th Year of Simulation), 2070 Climate Baseline

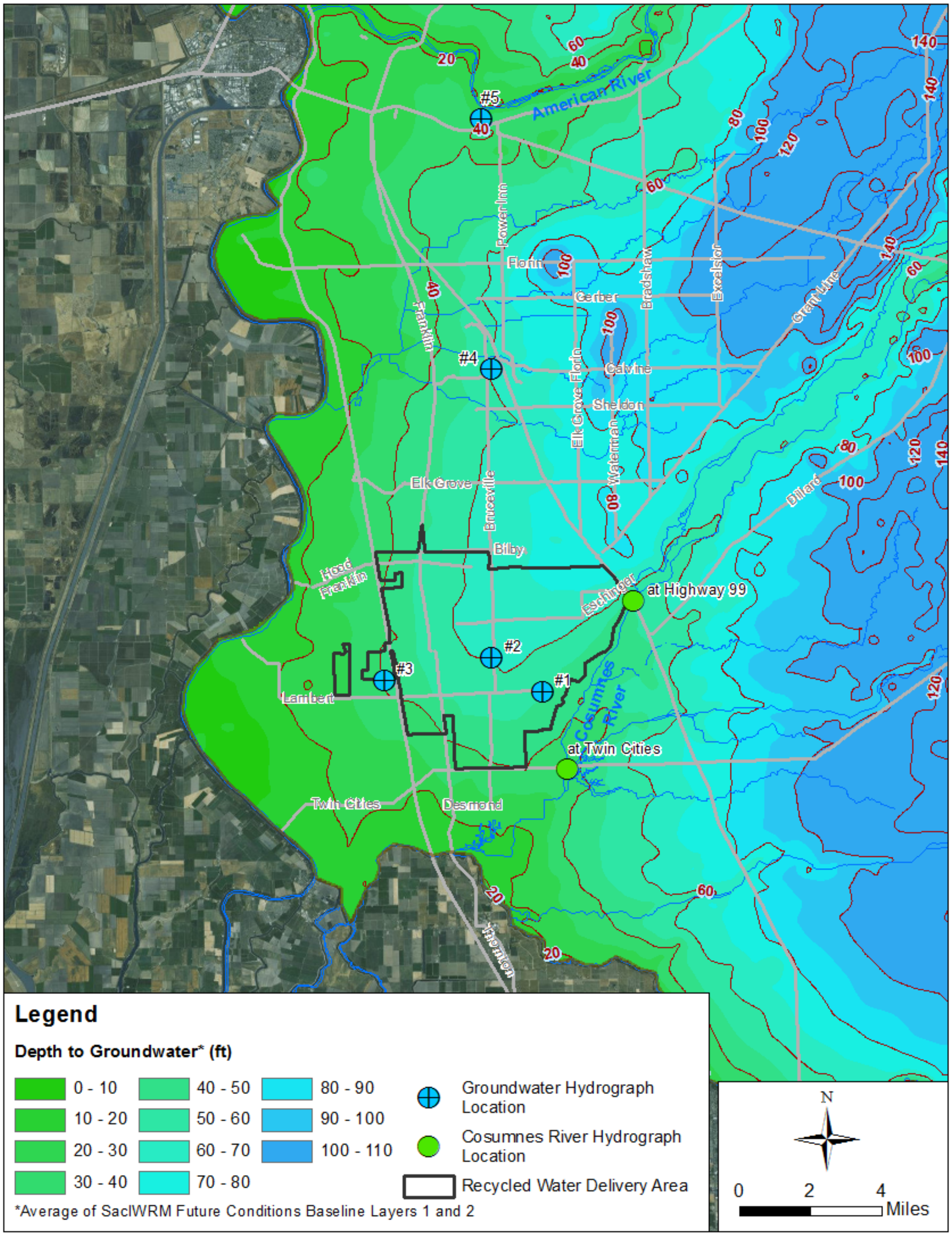


Figure 25: Depth to Groundwater, Wet Year (Fall 1984, 57th Year of Simulation), 2070 Climate Baseline

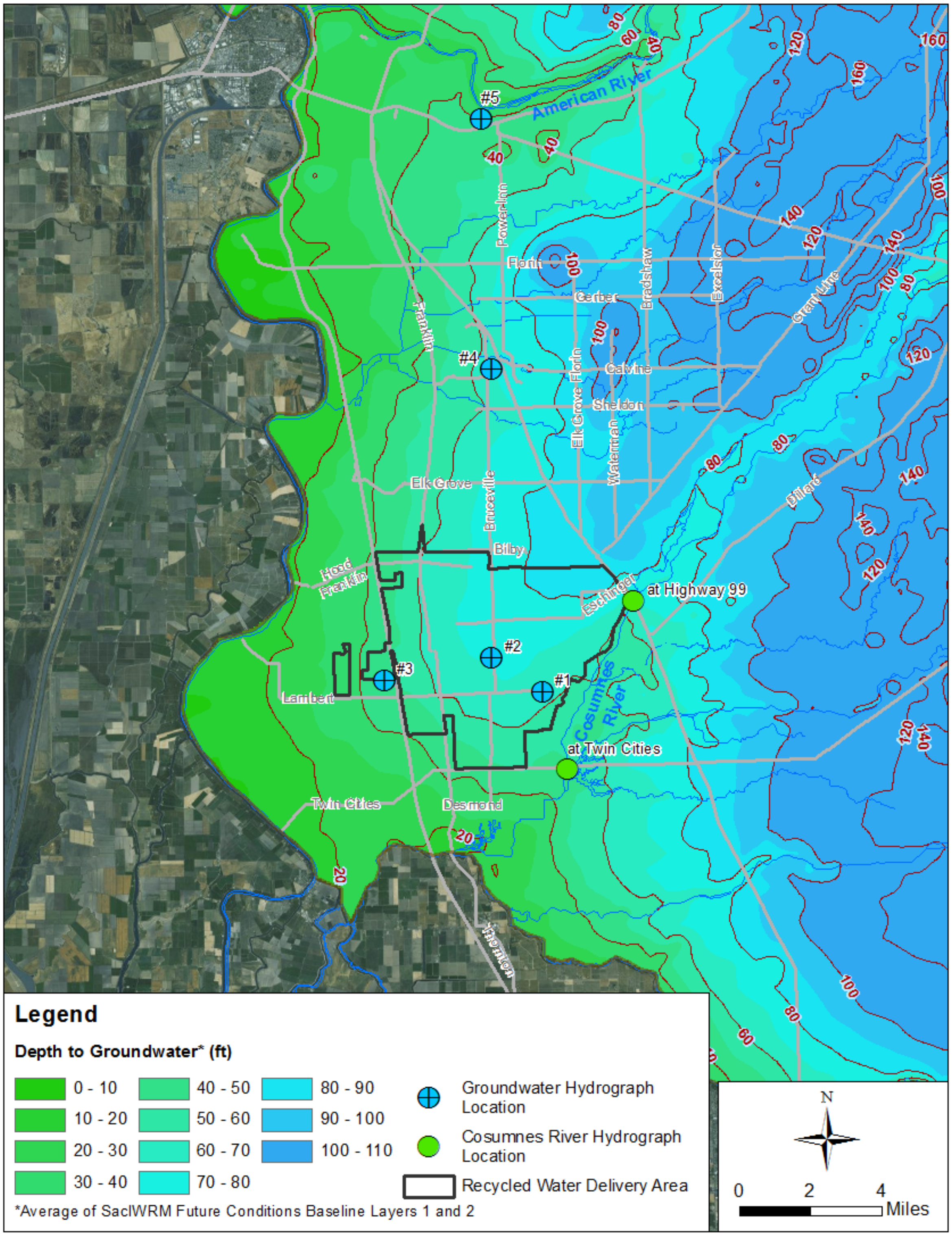


Figure 26: Depth to Groundwater, Dry Year (Fall 1994, 67th Year of Simulation), 2070 Climate Baseline

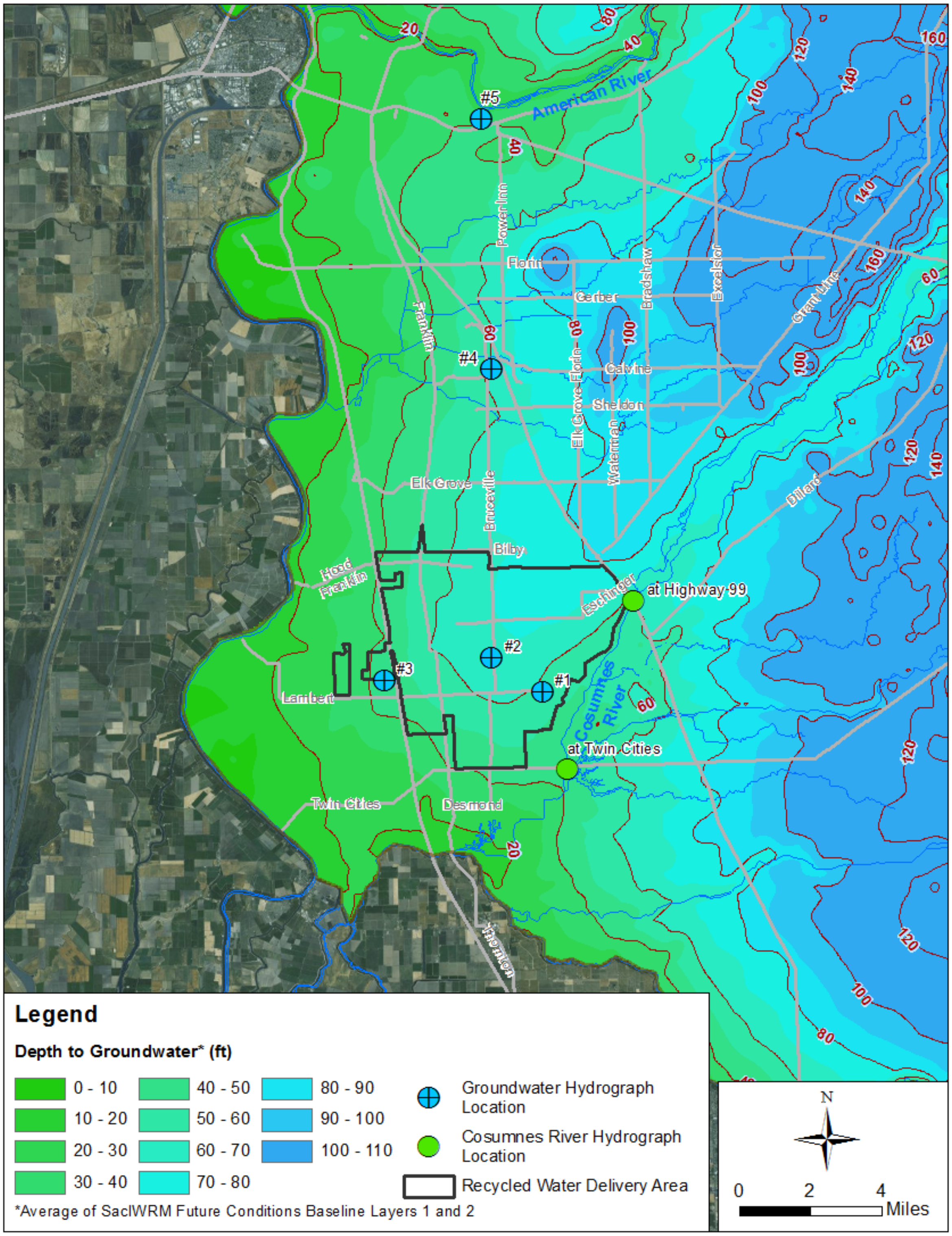
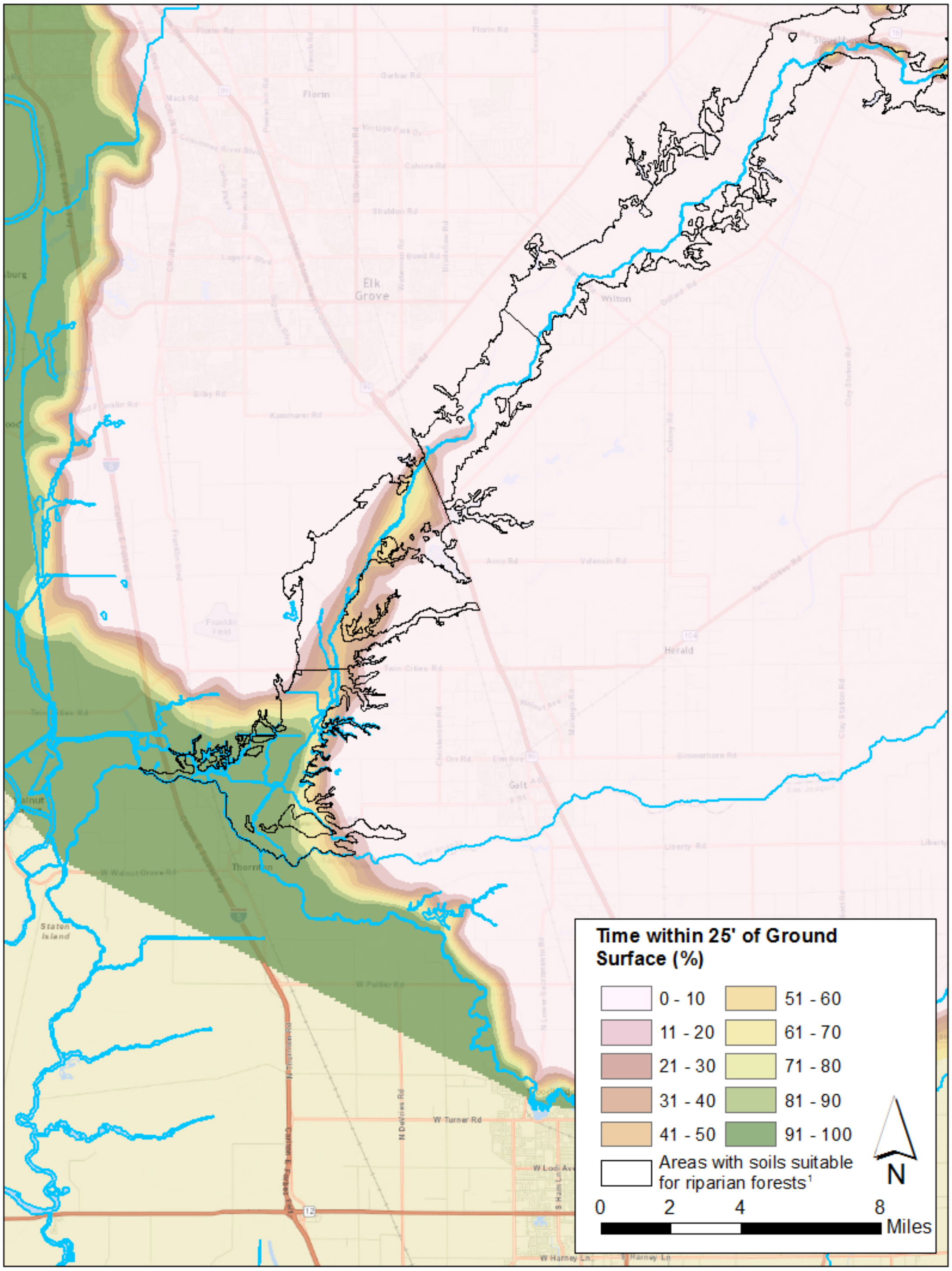


Figure 27: Depth to Groundwater, Normal Year (Fall 2004, 77th Year of Simulation), 2070 Climate Baseline



1. Source TNC 2014

Figure 28: Percent of Time Groundwater Levels are within 25 feet of the Ground Surface, 2070 Climate Baseline

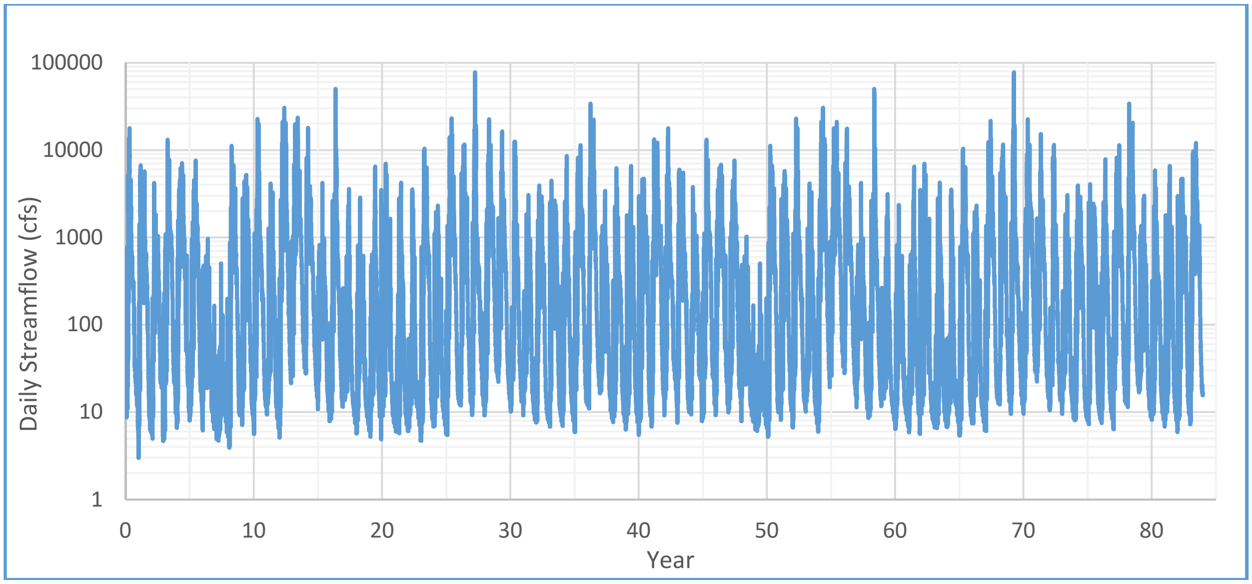


Figure 29: Streamflow Hydrograph at Cosumnes River at Highway 99 (McConnell Gage), 2070 Climate Baseline

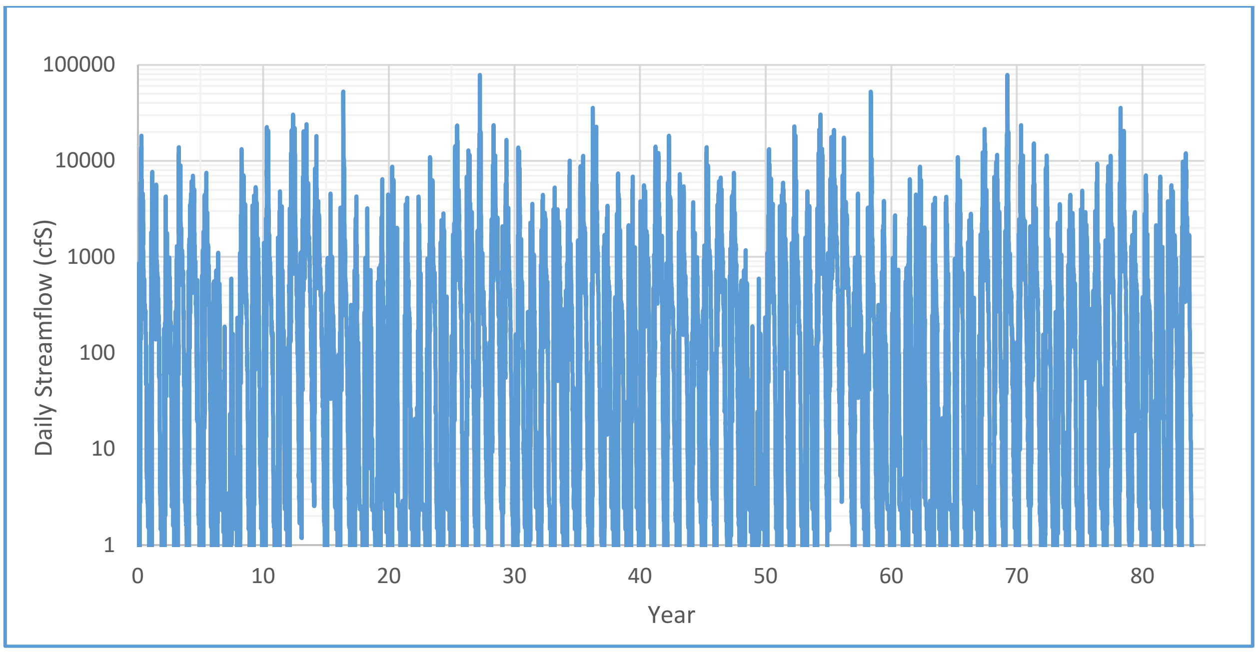


Figure 30: Streamflow Hydrograph at Cosumnes River at Twin Cities Road, 2070 Climate Baseline

3 Project Scenario Modeling

The Project 2030 and 2070 Scenarios include three components:

- In -lieu recharge, with recycled water deliveries replacing groundwater extraction;
- Wintertime irrigation utilizing recycled water to support groundwater replenishment; and,
- Extraction of stored water, using existing municipal groundwater wells.

3.1 In-Lieu Recharge

The in-lieu recharge component of the proposed South County Ag Program as developed for the WSIP grant application includes delivery of recycled water to agricultural uses in-lieu of groundwater pumping and for wintertime irrigation to support groundwater replenishment. Figure 31~~Figure 31~~ shows the areas that are considered for recycled water delivery.

Recycled water would be provided to approximately 16,000 acres of agricultural land for irrigation, shown in Figure 31~~Figure 31~~. Landowners covering a majority of the acreage in the project area have already submitted letters of interest, and coordination with additional landowners is ongoing. Recycled water delivery is only a portion of the total effluent from Regional San's treatment plant.

The volume of delivered recycled water was based on existing average annual estimates. As the SacIWRM uses a time series of monthly hydrology over the 1970-2011 time period, these estimates required refinement to reflect the differences in agricultural demand resulting from differences in precipitation. An infrastructure-based limitation of a maximum delivery of 6,400 acre-feet (AF) per month was utilized. Based on the project description, the overall annual average project delivery is assumed to be 32,572 AFY, maintaining the same value as used in modeling for the EIR. However, recycled water deliveries are assumed to be reduced in certain dry years, approximately when storage in Lake Shasta falls below 2,400,000 AF in April. During these periods, in-lieu recycled water deliveries are simulated as reduced by 50 percent for the duration of the irrigation season. The 50% reduction was used in the CalSim-II modeling and was assumed to be reasonable to mitigate the Lake Shasta storage impacts as a result of climate change assumptions. While the modeling analysis assumed an even 50% reduction, in practice, the actual pattern of reductions could be varied to reduce impacts to the delivered recycled water in-lieu of groundwater pumping. Over the 42-year hydrology (1970-2011), this occurs in only one year with the 2030 Climate Baseline and in only four years with the 2070 Climate Baseline. Since the SacIWRM simulates the 42-year hydrology twice, over the entire 84-year of simulation period, this occurs in two years with the 2030 Climate Baseline and in eight years with the 2070 Climate Baseline.

The simulation of application of recycled water in the SacIWRM is based on model subregions. The majority of the recycled water delivery area is located within Subregion 43 along with a small area in Subregion 42, as shown in Figure 32~~Figure 32~~. The project-provided recycled water, and the associated decreased groundwater extraction, is spread across these two subregions based on the parcel-based demand estimates. This results in Subregion 42 receiving, on average, approximately 1,100 AFY of recycled water (3% of the total) and Subregion 43 receiving approximately 31,000 AFY (97% of the total) under the Project 2030 Scenario. Under the Project 2070 Scenario, Subregion 42 would receive approximately 1,100 AFY of recycled water (4% of total) and Subregion 43 would receive 29,900 AFY (96% of the total). The reduction of pumping occurs in the same volumes and percentages. The total agricultural demand within the project area is estimated to be 44,300 AFY for the 2030 Climate Baseline and 50,600 AFY for the 2070 Climate Baseline. The remaining mid-summer demand of 12,200 AFY for the 2030 Climate Baseline and 19,600 AFY for the 2070 Climate Baseline would continue to be met by groundwater pumping as it is less economical to build infrastructure to meet peak summer demands with recycled water.

Within each subregion of the SacIWRM, use of recycled water is distributed at the model-element scale (Figure 33~~Figure 33~~). For each element within the project footprint, groundwater extraction is reduced and an equivalent volume of recycled water is delivered based on the proposed spatial and temporal distribution of recycled water.

3.2 Wintertime Irrigation to Support Groundwater Replenishment

The South County Ag Program also includes a wintertime irrigation component that compliments and augments the benefits seen from in-lieu recharge. Wintertime irrigation allows for continued replenishment of the groundwater system when agricultural demands are inadequate to allow for in-lieu recharge. This is accomplished through the delivery of recycled water for agricultural over-irrigation from November to March. This element of the Program provides many additional benefits:

- Increases the overall recharge of the aquifer system
- Recharges water when there is no need or reduced needs for water in the Sacramento River system
- Provides groundwater replenishment to the aquifer system while maintaining agricultural habitat that is critical to bird species
- Keeps recycled water moving in the distribution system to minimize operational issues that can be caused by stagnant water
- Provides these additional benefits with minimal additional capital investment

Wintertime agricultural recharge that was used in modeling for the EIR was approximately 17,500 AFY. Conceptually, the approach used for wintertime irrigation for the WSIP grant application is the same as in the EIR modeling analysis: delivery of recycled water for recharge by agricultural over-irrigation from November to March (with no assumed diluent water) uniformly applied across the project area. Wintertime irrigation is applied at a volume to result in 50,000 AF of total recycled water deliveries during each year. It is assumed that all water recharges the aquifer system, with evapotranspirative losses being small due to the wintertime period and similar to baseline, again due to the winter period. It is further assumed that no diluent water is applied, with regulatory approval based on a combination of precipitation, underflow, and potential future regulatory changes.

As a result of reduction in recycled water delivery in certain dry years when storage in Lake Shasta falls below 2,400,000 AF in April, the winter irrigation volume is assumed to increase to meet the total annual recycled water delivery of 50,000 AF. There is variability in the annual wintertime irrigation within the 2030 and 2070 Climate Change Baselines. Annual average wintertime irrigation is approximately 17,900 AFY under the Project 2030 Scenario, ranging from approximately 11,000 AF to 27,400 AF annually. Under the Project 2070 Scenario, annual average recharge is approximately 19,000 AFY, ranging from approximately 12,500 AF to 33,500 AF annually. As the in-lieu recharge is reduced due to storage conditions in Lake Shasta, annual average wintertime irrigation is assumed to increase by an equivalent volume to maintain the total project recharge capacity of 50,000 AFY. Since the Lake Shasta storage conditions are triggered more frequently with the 2070 Climate Baseline, the reduction in the in-lieu recharge is greater with the Project 2070 Scenario.

3.3 Extraction of Stored Water

Seventy percent of in-lieu recharged water is assumed to be unavailable for extraction, and is intended to remain in storage to benefit ecosystems, groundwater users, partially or fully mitigate losses, and contribute to overall basin sustainability. The remaining 30 percent of recharged water is assumed to be available for extraction, occurring during the driest 30 percent of years and recovering an average amount of banked water equivalent to the annual average in-lieu recharged volume. Wintertime irrigation and recharge is not accounted for in the project extraction.

For modeling purposes, during the identified dry periods, it is hypothetically assumed that the City of Sacramento and the Sacramento County Water Agency (SCWA), or their respective wholesale customers, would limit their surface water diversions and shift to groundwater pumping of the banked water. Regional San is having ongoing discussions of the proposed project banking and recharge operations with the Sacramento Central Groundwater Authority, which includes a broad consortium of these agencies, including the City of Sacramento and Sacramento County. Although no final agreements have been reached with these agencies, the proposed project banking and recharge operations are consistent with the conjunctive use plans of these agencies. The proposed project extractions will be further refined in coordination with the Sacramento Central Groundwater Authority and its member agencies as a water accounting framework and groundwater bank is developed, along with additional environmental analysis. This recovery could allow for the sale of the surface water to other entities and/or improved reliability. It is assumed that approximately 32,572 AFY would be available for extraction in the driest 30 percent of years based on recovery at the rate of recharge, when banked water is available. The extraction is ceased when the “banked” water reaches zero to avoid extracting more than 30 percent of recharged water. Accounting based on these assumptions is shown in Figure 34~~Figure 34~~ under the Project 2030 Scenario and in Figure 35~~Figure 35~~ under the Project 2070 Scenario.

In this hypothetical scenario, SCWA and the City of Sacramento are assumed to pump banked groundwater while reducing their surface water use. The total available volume is split between

SCWA and the City of Sacramento proportionally to the general understanding of available capacity in existing groundwater wells. It was assumed that the City of Sacramento and SCWA, or their respective wholesale customers, would have the capability to extract up to approximately 32,572 AFY from groundwater and simultaneously reduce surface water diversions for the same amount. A variety of different users could extract the banked water, and they are likely to be located in a similar distance as the City of Sacramento and SCWA; thus, the results of this scenario could be used to provide some level of understanding of the impact of those different users.

Wells simulated as extracting groundwater are shown in Figure 36~~Figure 36~~, showing 21 wells identified for SCWA and four wells for the City of Sacramento. These locations are selected to be relatively close to the area of in-lieu recharge while still within the purveyor's distribution system, meaning south of the American River for the City of Sacramento and within the South Service Area for SCWA. As discussed above, it was assumed that 32,572 AFY of groundwater would be extracted from existing facilities by the City of Sacramento and SCWA, or their respective wholesale customers, with a commensurate reduction in surface water diversions by those entities. Project-provided recycled water would continue to be delivered to the agricultural users under the in-lieu recharge and winter agricultural recharge components of the program. The groundwater extraction in areas further away from the project area is anticipated to have less impacts on the overall project benefits gained from the groundwater recharge, as further explained in Section 4, Results.

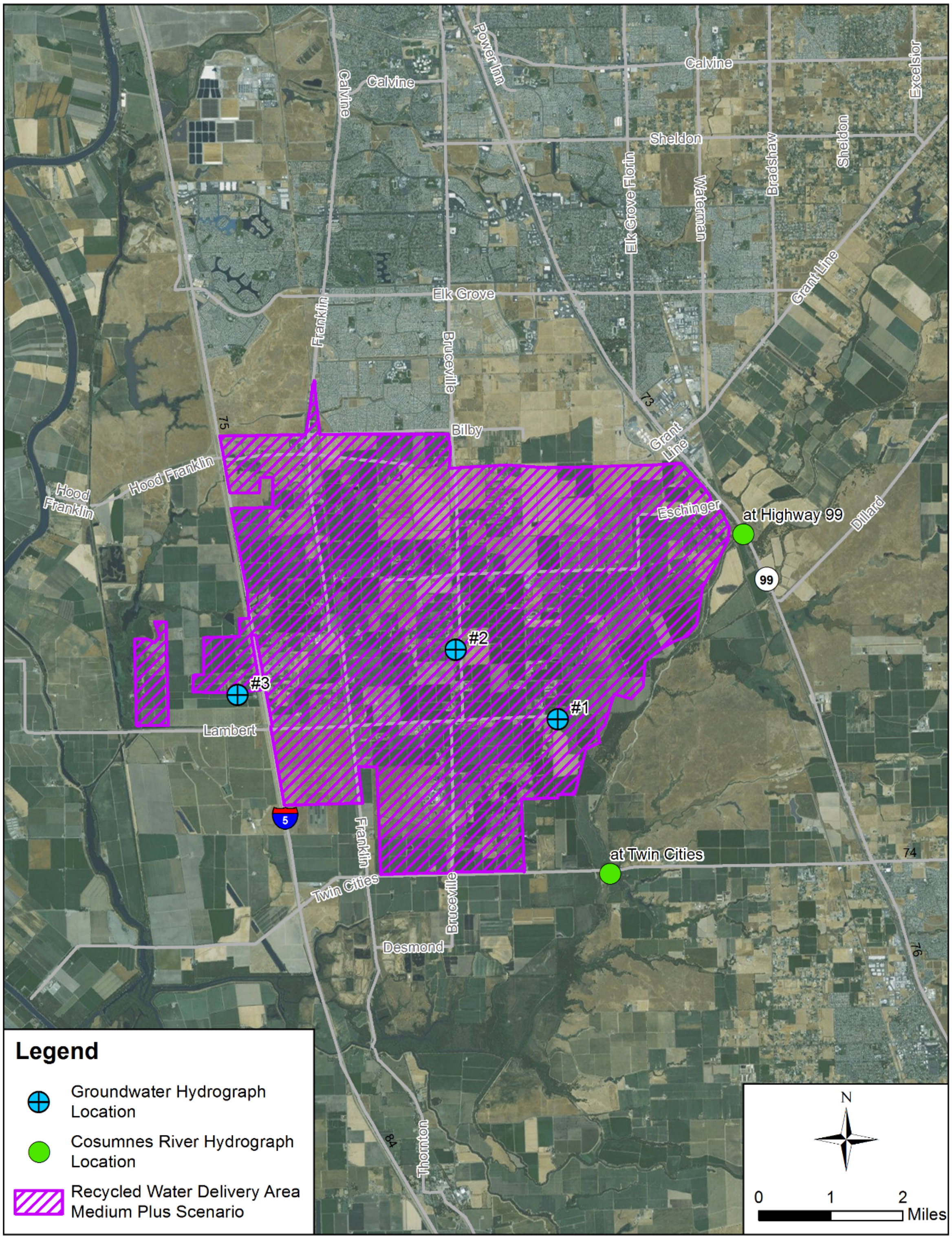


Figure 31: Agricultural Lands Served by Recycled Water, Project Scenario

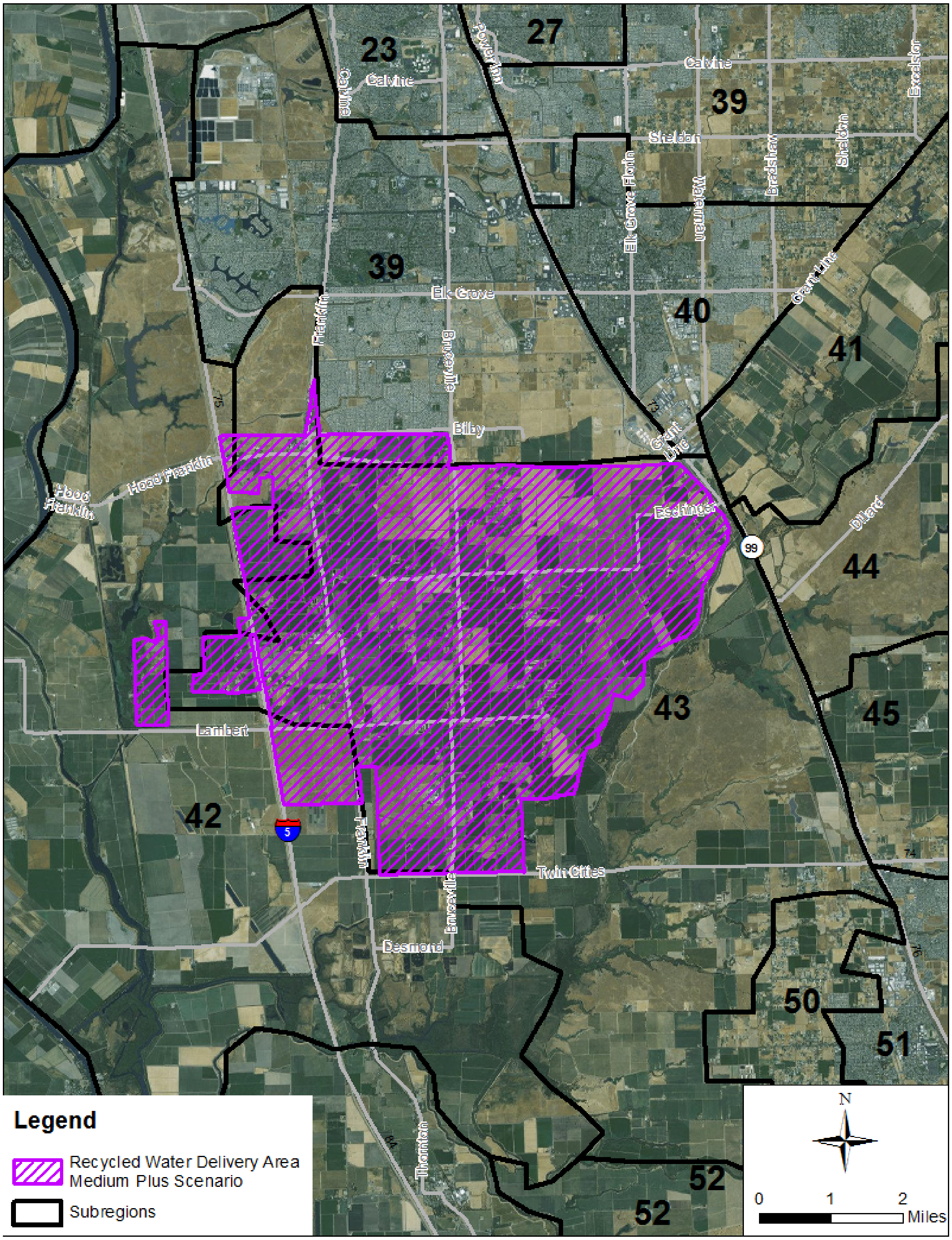


Figure 32: SacIWRM Subregions and Agricultural Lands Served by Recycled Water

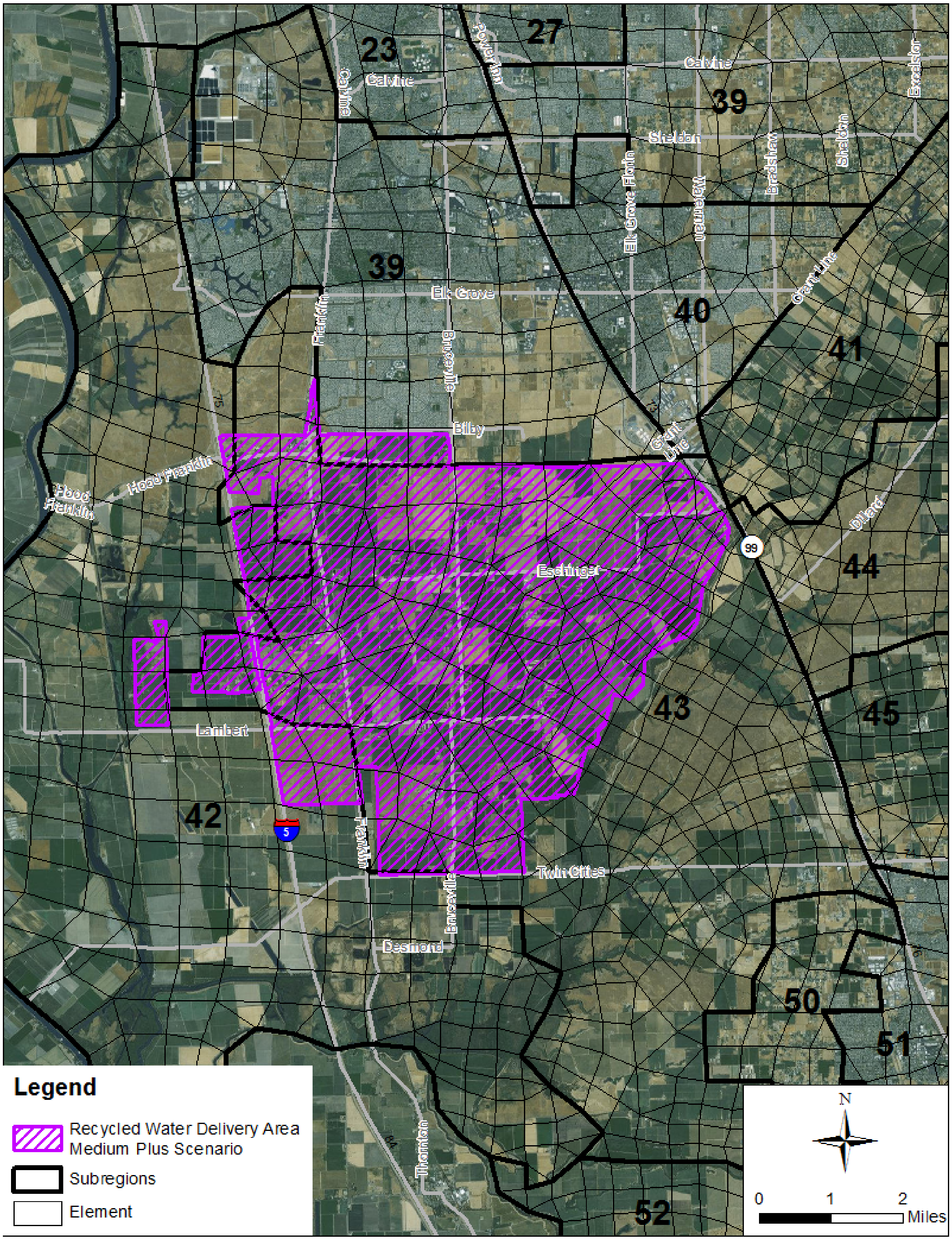


Figure 33: SacIWRM Subregions, Model Elements, and Agricultural Lands Served by Recycled Water

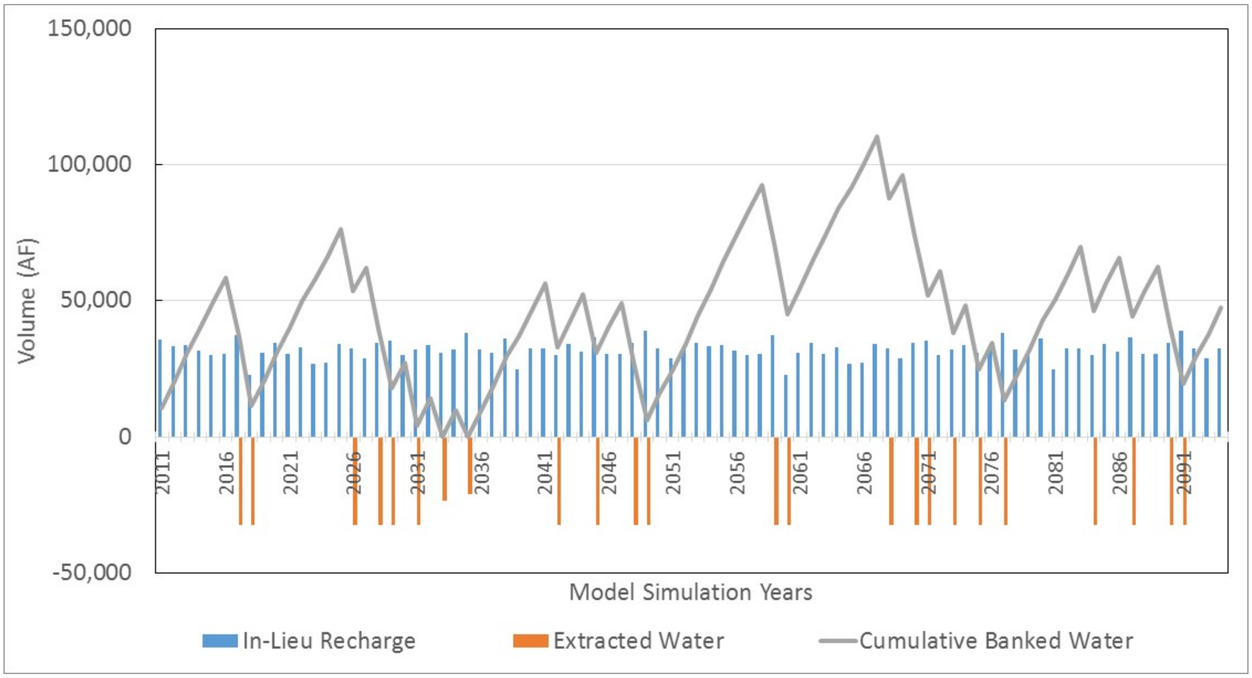


Figure 34: Project 2030 Scenario - Accounting of In-Lieu Recharge, Extraction, and Cumulative Banked Water

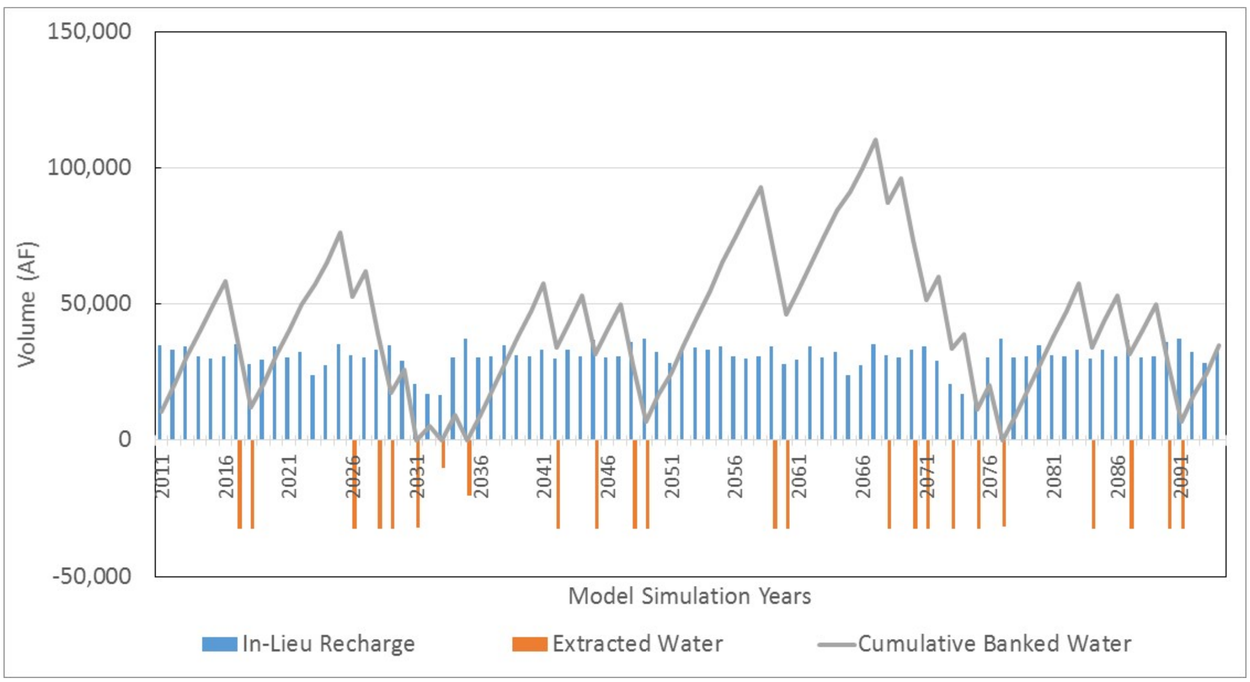


Figure 35: Project 2070 Scenario - Accounting of In-Lieu Recharge, Extraction, and Cumulative Banked Water

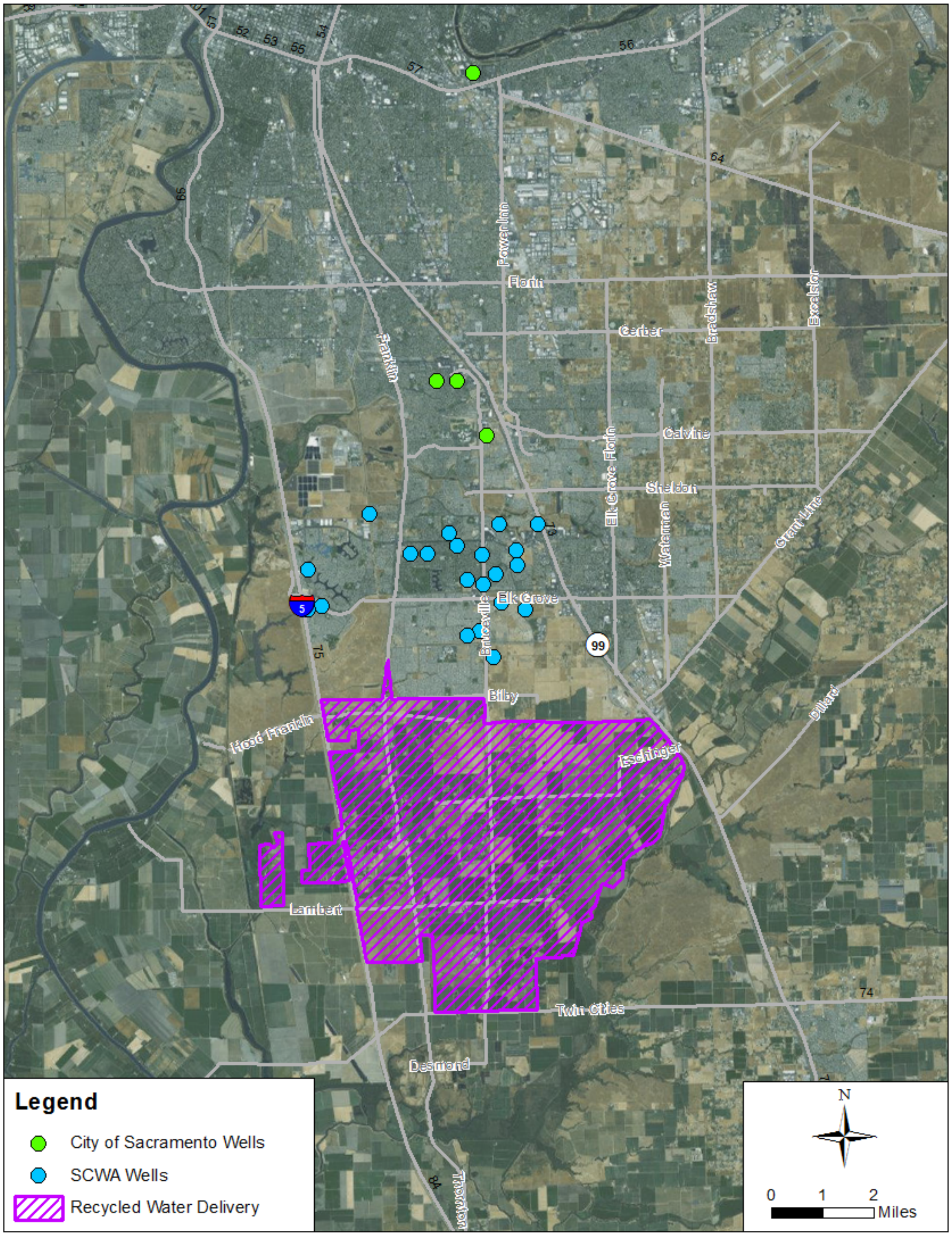


Figure 36: Location of Existing Recovery Wells

4 Results

The model results for the Project 2030 Scenario relative to the 2030 Climate Baseline and the Project 2070 Scenario relative to the 2070 Climate Baseline are described in the following sections.

4.1 Project 2030 Scenario

The Project 2030 Scenario with the 2030 climate conditions results in an increase in groundwater elevations in and near the Project area. This increase in groundwater elevations results in reduced recharge from surface water courses, particularly from the Cosumnes River. Additionally, inflows from surrounding basins are reduced, particularly from the Solano Subbasin in Yolo County and the Eastern San Joaquin Subbasin to the south of the Mokelumne River.

The results of Project 2030 Scenario with the 2030 climate conditions are summarized in the following figures:

- Groundwater hydrographs at three locations, shown on Figure 37~~Figure 37~~
    - Hydrograph for Location 1: Figure 38~~Figure 38~~
    - Hydrograph for Location 2: Figure 39~~Figure 39~~
    - Hydrograph for Location 3: Figure 40~~Figure 40~~
    - Hydrograph for Location 3: Figure 41~~Figure 41~~
    - Hydrograph for Location 3: Figure 42~~Figure 42~~
- Groundwater elevation maps for three selected dates, representing different hydrologic conditions
    - Wet (fall 1984): Figure 43~~Figure 43~~
    - Dry (fall 1994): Figure 44~~Figure 44~~
    - Normal (fall 2004): Figure 45~~Figure 45~~
- Change in groundwater elevation maps for three selected dates, representing different hydrologic conditions
    - Wet (fall 1984): Figure 46~~Figure 46~~
    - Dry (fall 1994): Figure 47~~Figure 47~~
    - Normal (fall 2004): Figure 48~~Figure 48~~
- Depth to groundwater maps for three selected dates, representing different hydrologic conditions
    - Wet (fall 1984): Figure 49~~Figure 49~~
    - Dry (fall 1994): Figure 50~~Figure 50~~
    - Normal (fall 2004): Figure 51~~Figure 51~~
- Percent of time groundwater levels are within 25 feet of the ground surface: Figure 52~~Figure 52~~
- Time series chart of change in groundwater volume, compared to the 2030 Climate Baseline: Figure 53~~Figure 53~~

- Streamflow exceedance charts at two locations, shown on Figure 16~~Figure 16~~
    - Cosumnes River at Highway 99 (McConnell gage): Figure 54~~Figure 54~~
    - Cosumnes River at Twin Cities Road: Figure 55~~Figure 55~~
- Table of groundwater storage, inflows, and outflows, compared to the 2030 Climate Baseline: Table 2

The Project 2030 Scenario simulates reduction of recycled water deliveries to the in-lieu service area during the dry periods when the Lake Shasta storage falls below a threshold. This occurs in one year under the 42-year hydrology in the 2030 climate conditions. While the in-lieu recharge benefits are reduced, the wintertime irrigation makes up for the difference to maintain the Project recharge capacity at 50,000 AFY.

The groundwater hydrographs show how groundwater elevations change under the 2030 Climate Baseline and the Project 2030 Scenario. Groundwater elevations increase due to the project approximately 25 feet after 15 years near the center of the project at hydrograph location 2 (Figure 39~~Figure 39~~, with location shown in Figure 37~~Figure 37~~), generally stabilizing at a long-term increase of approximately 35 feet. Groundwater elevation increases are smaller towards the boundaries of the Project Area, with hydrograph location 1 (Figure 38~~Figure 38~~) and hydrograph location 3 (Figure 40~~Figure 40~~) showing long-term project-related increases in groundwater elevation of approximately 25 feet at both locations.

Extraction of up to 30 percent of the banked water results in slightly lowered groundwater elevations near and around the extraction wells used for the extraction of the project banked water during the extraction years. Groundwater levels decrease during extraction years below the 2030 Climate Baseline and recover to remain at or above the 2030 Climate Baseline during non-extraction years as a result of the ongoing in-lieu recharge and wintertime irrigation. At the end of the 84 years of the simulation, groundwater levels remain above the 2030 Climate Baseline at location 4 (Figure 41~~Figure 41~~) and at approximately the same level at location 5 (Figure 42~~Figure 42~~).

Groundwater flow direction is shown through groundwater elevation maps. Comparison of groundwater elevation maps from the Project 2030 Scenario (Figure 43~~Figure 43~~-Figure 45~~Figure 45~~) to those from the 2030 Baseline (Figure 46~~Figure 46~~ - Figure 48~~Figure 48~~) shows that groundwater elevations rise in the project area and gradients change, but the general flow direction remains from the Cosumnes River towards regional pumping depressions in the Elk Grove area and the wells pumping for the project extraction.

Change in groundwater elevation maps emphasize where groundwater elevations increase as a result of the project. As described above, groundwater elevations increase most in the center of the project area, up to approximately 30 feet compared to the 2030 Baseline (Figure 46~~Figure 46~~ - Figure 48~~Figure 48~~). The area with at least 10-15 feet increase in groundwater elevations extends to just beyond the project boundaries. Hydrologic conditions have only a small impact on the project-related increases in groundwater elevation, with slightly larger increases compared to the 2030 Baseline during dry periods as opposed to wetter periods. During the wet periods, the overall increase in groundwater elevations spread over larger areas beyond the Project area compared to the normal and dry periods. Extraction of the project banked water results in lowered groundwater elevations near and around the extraction wells used for extraction of the banked water during the extraction years. Overall, the drawdown is mainly at and near the extraction wells during normal and dry years. The largest change in groundwater levels range from 5-10 feet at and near the extraction wells with no decline in groundwater levels away from the wells and further away from the project area. Overall, the groundwater extraction in areas further away from the project area would have less impacts on the overall project benefits gained from the groundwater recharge.

Depth to groundwater maps provide information on the lift required to pump groundwater and on the overall ability for wells to pump water. The depth to groundwater in the project area improves due to the in-lieu recharge (Figure 49~~Figure 49~~ - Figure 51~~Figure 51~~) compared to depths under the 2030 Climate Baseline conditions (Figure 10~~Figure 10~~ - Figure 12~~Figure 12~~). Depths to groundwater decrease to a minimum of approximately 10-20 feet near the southwestern portion of the project area. Near the Cosumnes River, depths to groundwater decrease to a minimum of approximately 20-40 feet below ground surface, depending on water year types, with greater depth to groundwater during dry years.

Similar to the depth maps, potential benefits to riparian forests are summarized by showing the percentage of time groundwater levels would be within 25 feet of the surface[4] (Figure 52~~Figure 52~~). While the rooting depth of riparian forests are highly variable depending on species, age, soils, and other factors, 25 feet is used as a comparison threshold to quantify benefits to riparian forests. 25 feet was selected in coordination with staff from The Nature Conservancy as a metric for riparian health. The ability of riparian forest to withstand periods of low groundwater elevations is also variable; the area with groundwater elevations within 25 feet of the surface 90% of the time is used for the comparison threshold. For the Project 2030 Scenario, approximately 15,500 acres meet this threshold in areas with suitable soils for riparian forests, mostly focused in the area of the Cosumnes River south of Highway 99. This is considerably higher than the 7,100 acres meeting the threshold under the 2030 Climate Baseline. Note that this acreage represents potential acreage for riparian forests; actual increases in riparian forests, and associated changes in water use, generally requires changes in land use practices and/or land management and is not included in the simulations.

It should be noted, that for the purpose of quantifying and monetizing the potential benefits of the program to support riparian and wetland plant communities, two shallow groundwater depths were selected by the Freshwater Trust in the South Sacramento County Agriculture and Habitat Lands Recycled Water, Groundwater Storage, and Conjunctive Use Program: Conceptual Ecological Plan and Ecosystem Benefits (page 16): (1) 5 feet below the ground surface, and (2) 10 feet below the ground surface. These two depths were selected to represent the range of

[4] As this figure focuses on shallow groundwater conditions, the information presented here represents conditions in Layer 1 of the SacIWRM, while previous figures represent an average of Layer 1 and Layer 2.

supporting conditions for mature species, as well as seedling establishment, and are considered conservative. The accuracy of the groundwater modeling was also taken into consideration when selecting these two depths. As such, these five-foot increments were selected to reflect the physical conditions necessary to support hydrophilic vegetation, while also remaining within the bounds of the predictive capacity of the groundwater model.

The higher groundwater elevations discussed above are a result of the increased groundwater in storage caused by in-lieu recharge and wintertime irrigation. The in-lieu recharge is achieved by supplying recycled water to participating growers, allowing pumps in groundwater wells to be turned off. Water that would have been pumped out of the aquifer is left in the aquifer, resulting in additional water in storage when compared to the 2030 Climate Baseline. Figure 53~~Figure 53~~ shows how storage increases in the basin as a result of the project by comparing the Project 2030 Scenario to the 2030 Climate Baseline. Storage initially increases rapidly, as most of the initial in-lieu recharge and wintertime irrigation go to increase groundwater in storage. After 10 years, approximately 500,000 AF has been recharged (combined in-lieu recharge and wintertime irrigation), with an increase in groundwater in storage of approximately 245,000 AF and the remainder resulting in increased streamflows or increased storage in adjacent basins. This suggests approximately 50% of the recharged water results in increased storage in the first 10 years. As groundwater levels rise with the continued recharge, less of the recharge contributes to groundwater storage and more contributes to streamflows or storage in adjacent basins. Based on the groundwater hydrographs, groundwater levels near the project area continue to increase in the first 15-20 years of the simulations, generally stabilizing thereafter. In the first 20 years of the simulation, 1,000,000 AF is recharged with an increase in groundwater storage of approximately 290,000 AF (or approximately 29% of the recharged water) under the Project 2030 Scenario. The most of the change in storage would occur in the first 20 years of the simulation. As the higher groundwater elevations increasingly interact with rivers and adjacent groundwater basins, this results in reduced groundwater recharge from rivers and reduced inflow from surrounding basins compared to the 2030 Climate Baseline. Generally, over a very long time frame, for groundwater systems that reach an equilibrium, there would be no additional increase in storage, and the full recharge volume would result in increases in streamflow, but such conditions are not reached within the 84-year simulation period analyzed for the proposed project, although they are approached. In the last 10 years of the simulation, the change in storage is significantly smaller compared to the first 20 years of the simulation - approximately 500,000 AF of water has been recharged, but the resulting increase in the storage is approximately 27,000 AF, or 5% of the recharged water, and the remainder resulting in increased streamflows or increased storage in adjacent basins. At the end of the simulation, increase in groundwater in storage reaches approximately 450,000 AF (Figure 53~~Figure 53~~).

Streamflow conditions are summarized in exceedance charts, which show the percentage of time that different daily streamflows are exceeded. The charts show that streamflows are higher during low-flow events under the Project 2030 Scenario at Twin Cities Road (Figure 55~~Figure 55~~, with location shown on Figure 37~~Figure 37~~), which could potentially benefit the riparian environment around the river. On an average, the daily streamflow would be approximately 22 cubic feet per second (cfs) higher under the Project 2030 relative to the 2030 Climate Baseline.

Under the Project 2030 Scenario, streamflows that are equal or greater than the average of 22 cfs would occur during 18,980 days (or 60 percent) of the simulation period. While there is small to negligible difference in flows in the Cosumnes River at Highway 99 (Figure 54~~Figure 54~~, with location shown on Figure 37~~Figure 37~~), the average daily streamflow would be approximately 3 cfs higher under the Project 2030 and streamflows that are equal or greater than the average of 3 cfs would occur during 12,200 days (or 40 percent) of the simulation period. The trends seen at these two locations is consistent with the change in groundwater elevation maps, which indicate higher groundwater elevations near the Cosumnes River generally downstream of Highway 99. These conditions result in less recharge from the Cosumnes River to groundwater and thus higher streamflows with benefits to streamflows, in particular during low-flow events.

Table 1 summarizes the water supply conditions in the project area on an average monthly basis for the Project 2030 Scenario and the 2030 Climate Baselines. The selected water budget components presented in Table 2 show increases in storage, decreases in recharge from rivers and streams, and decreases in inflows from surrounding subbasins. The relative contribution to storage compared to increased streamflow and decreased inflows from surrounding subbasins is much higher in the earlier years of the project, as discussed earlier. Likewise, in the later years of the project the relative contribution to increased streamflow and decreased inflows from surrounding subbasins is much higher than the relative contribution to storage. To provide information for this shift in benefits, the budget is presented for the full 84-year simulation as well as separately for the first half and second half in Table 2. The change in storage is estimated to be approximately 8,700 AFY in the first half of the simulation and reduces to 1,800 AFY in the second half of the simulation. This further illustrates the project benefits to the groundwater storage realized early on in the simulation. On the other hand, the gain from rivers and streams and inflows from the surrounding boundaries to the basin would be reduced (shown by negative sign) under the Project 2030 Scenario and the reduction would be much higher in the second half of the simulation than the first half. Further reduction in the second half illustrates the project benefits to increased streamflows and surrounding subbasins in later years of the simulation. Finally, increases in streamflow under the project conditions were provided for use in CalSim-II simulations that simulated the surface water conditions of the project under 2030 climate.

Figures and Tables: Project 2030 Scenario

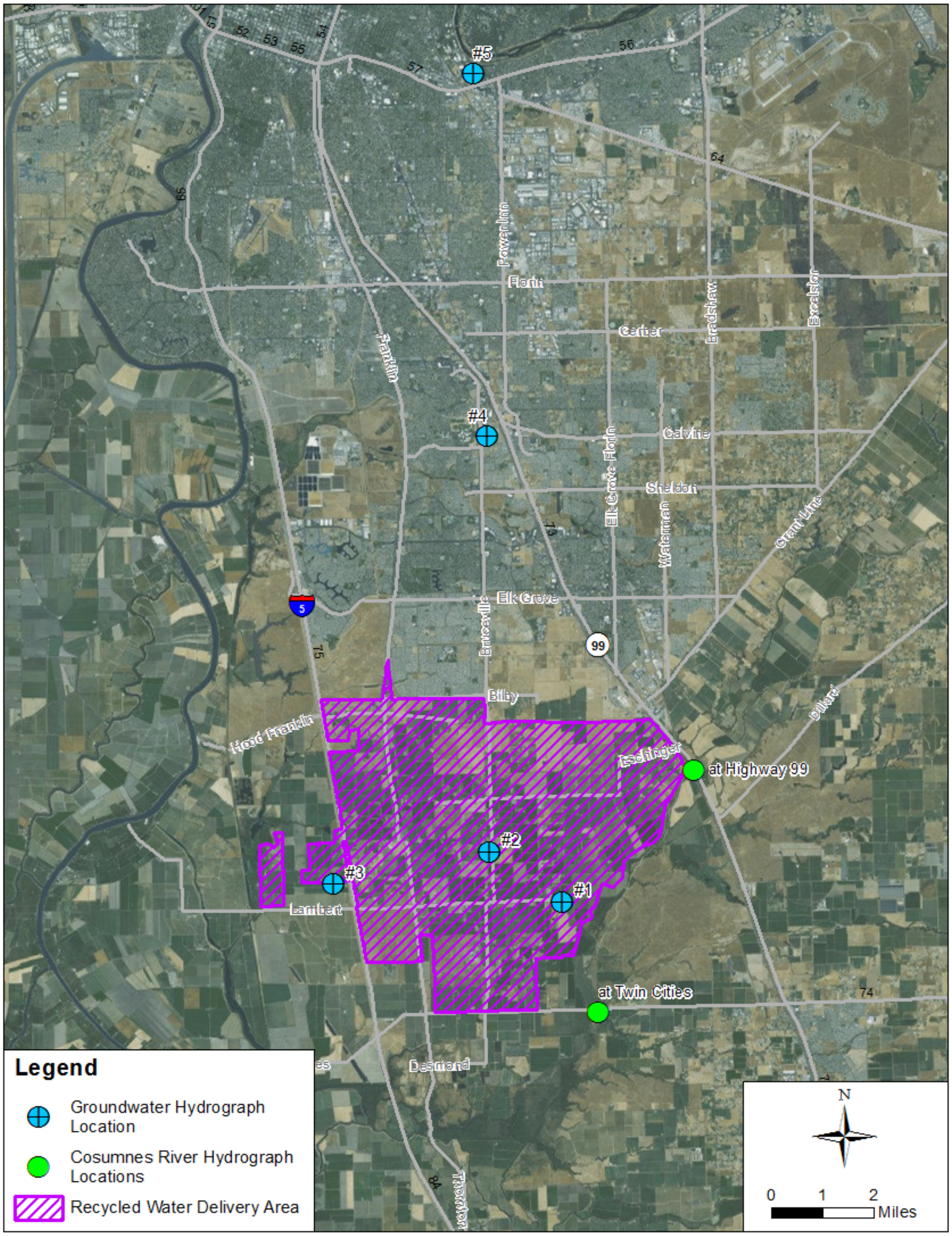


Figure 37: Project Location and Hydrograph Locations

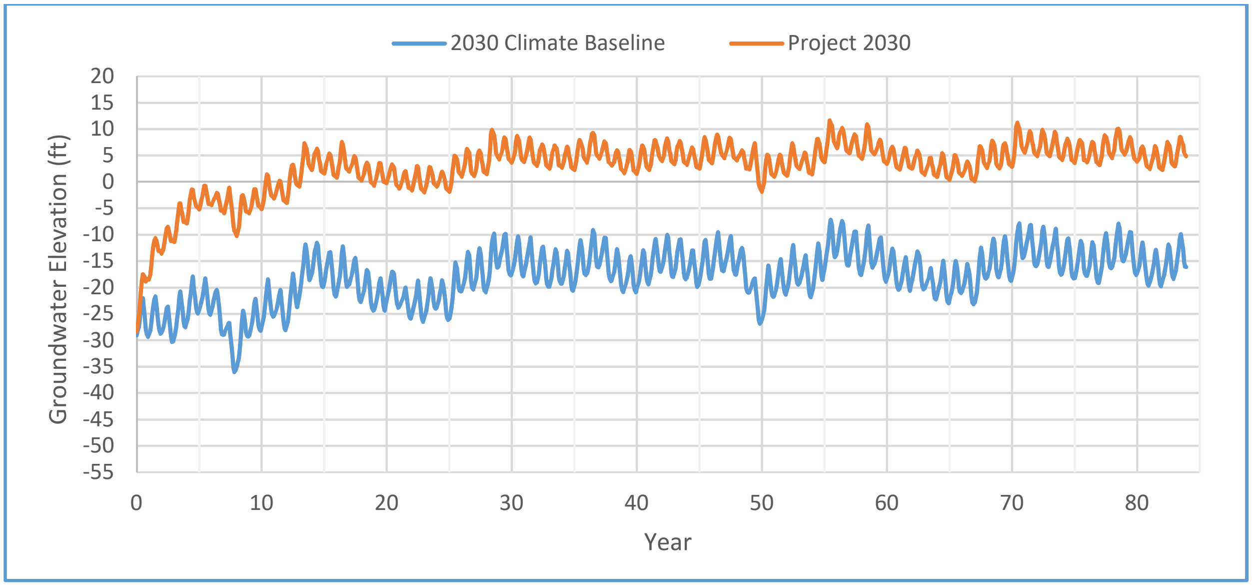


Figure 38: Groundwater Hydrograph at Location 1, Project 2030, Showing Response to Project Recharge near the Center of the Project Area

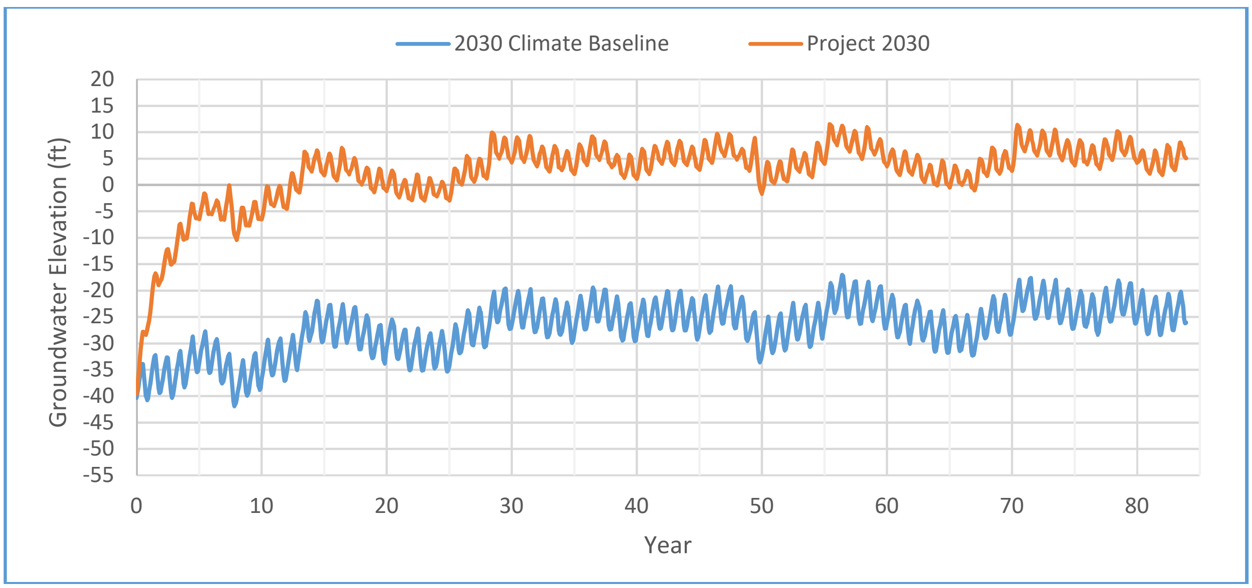


Figure 39: Groundwater Hydrograph at Location 2, Project 2030, Showing Response to Project Recharge at the Center of the Project Area

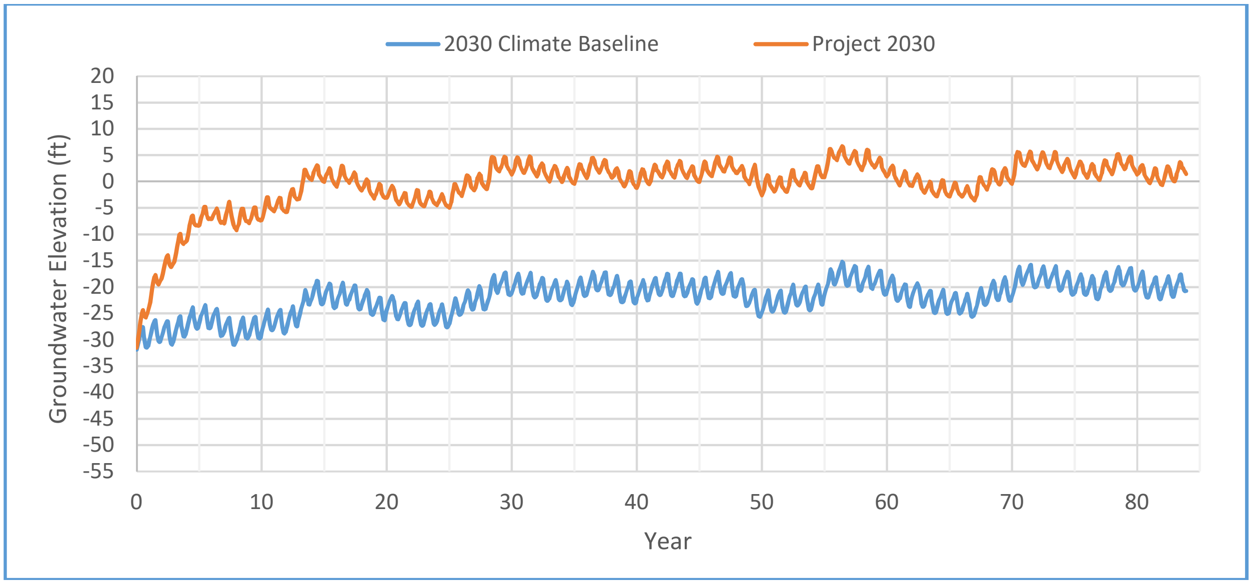


Figure 40: Groundwater Hydrograph at Location 3, Project 2030, Showing Response to Project Recharge near the Project Boundary

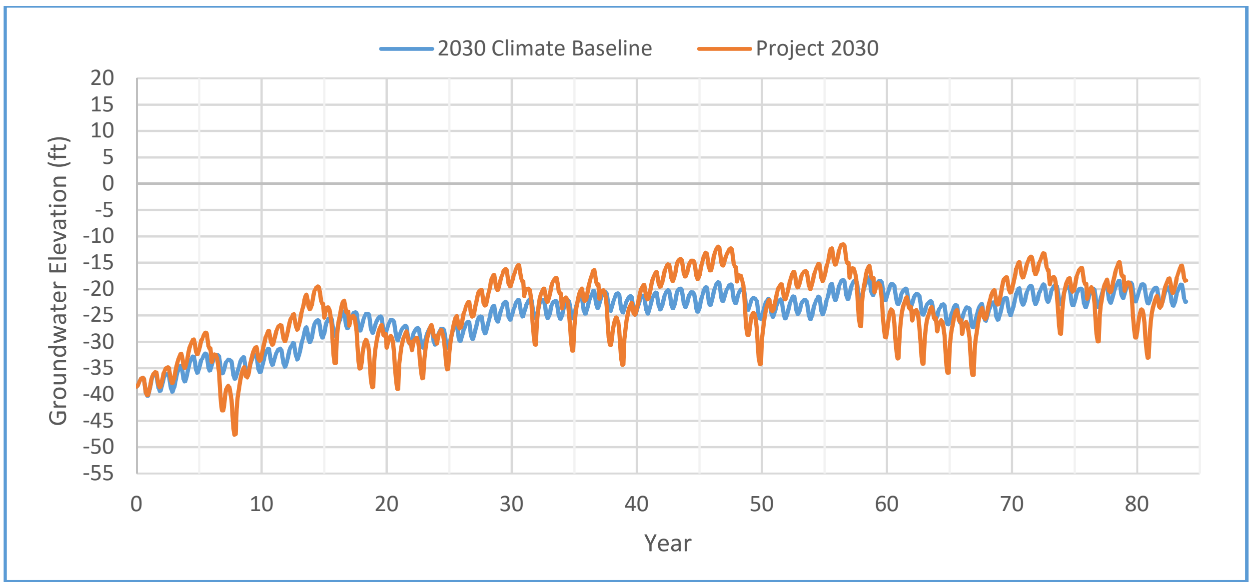


Figure 41: Groundwater Hydrograph at Location 4, Project 2030, Showing Response to Project Extraction near Extraction Wells

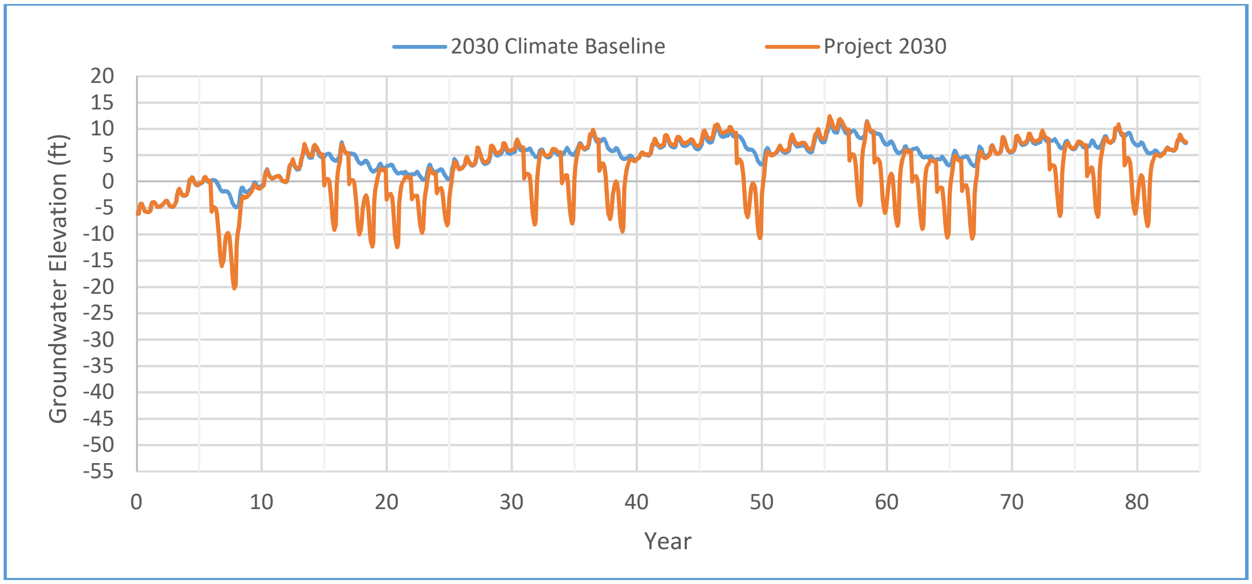


Figure 42: Groundwater Hydrograph at Location 5, Project 2030, Showing Response to Project Extraction near Extraction Wells

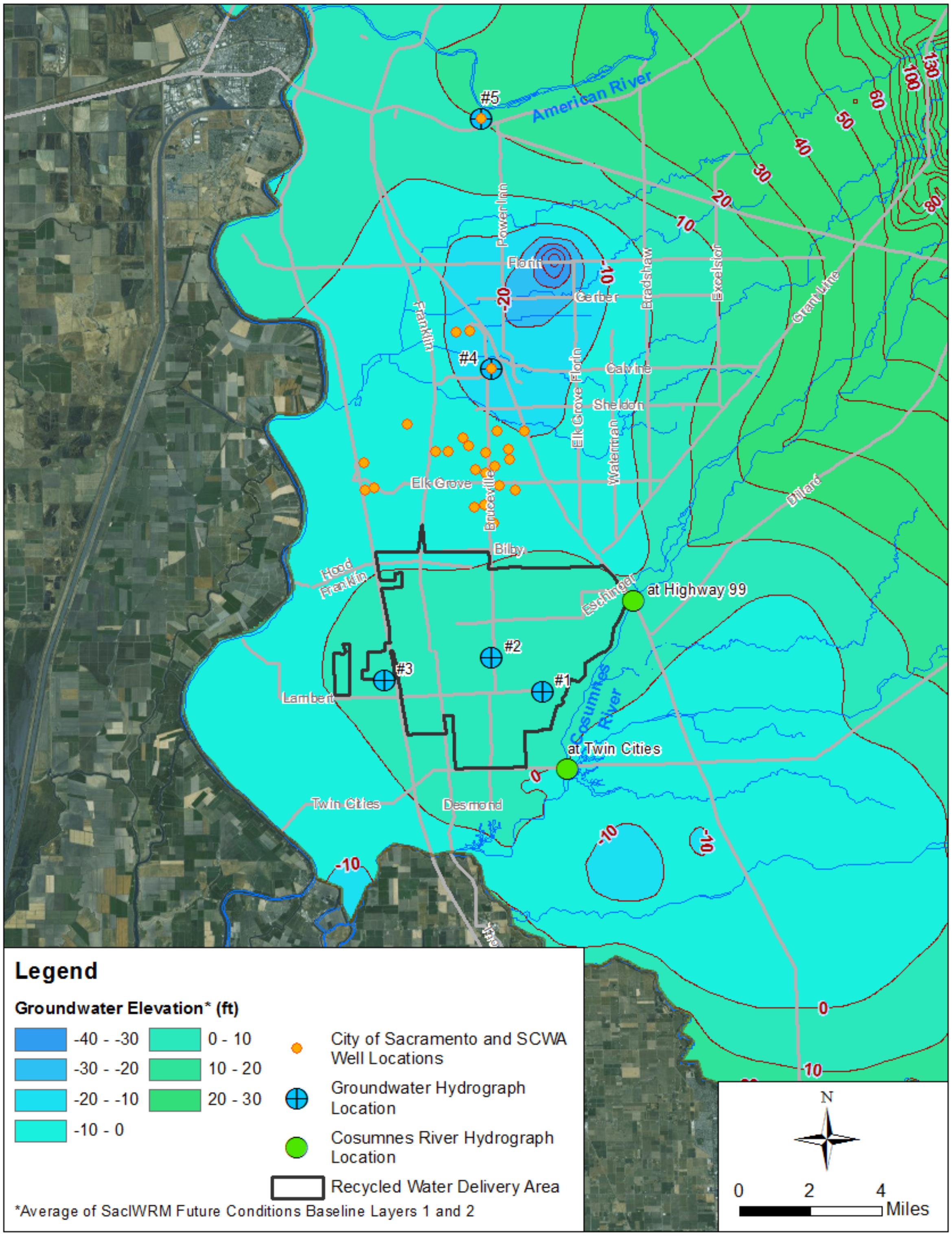


Figure 43: Groundwater Elevation, Wet Year (Fall 1984, 57th year of simulation), Project 2030

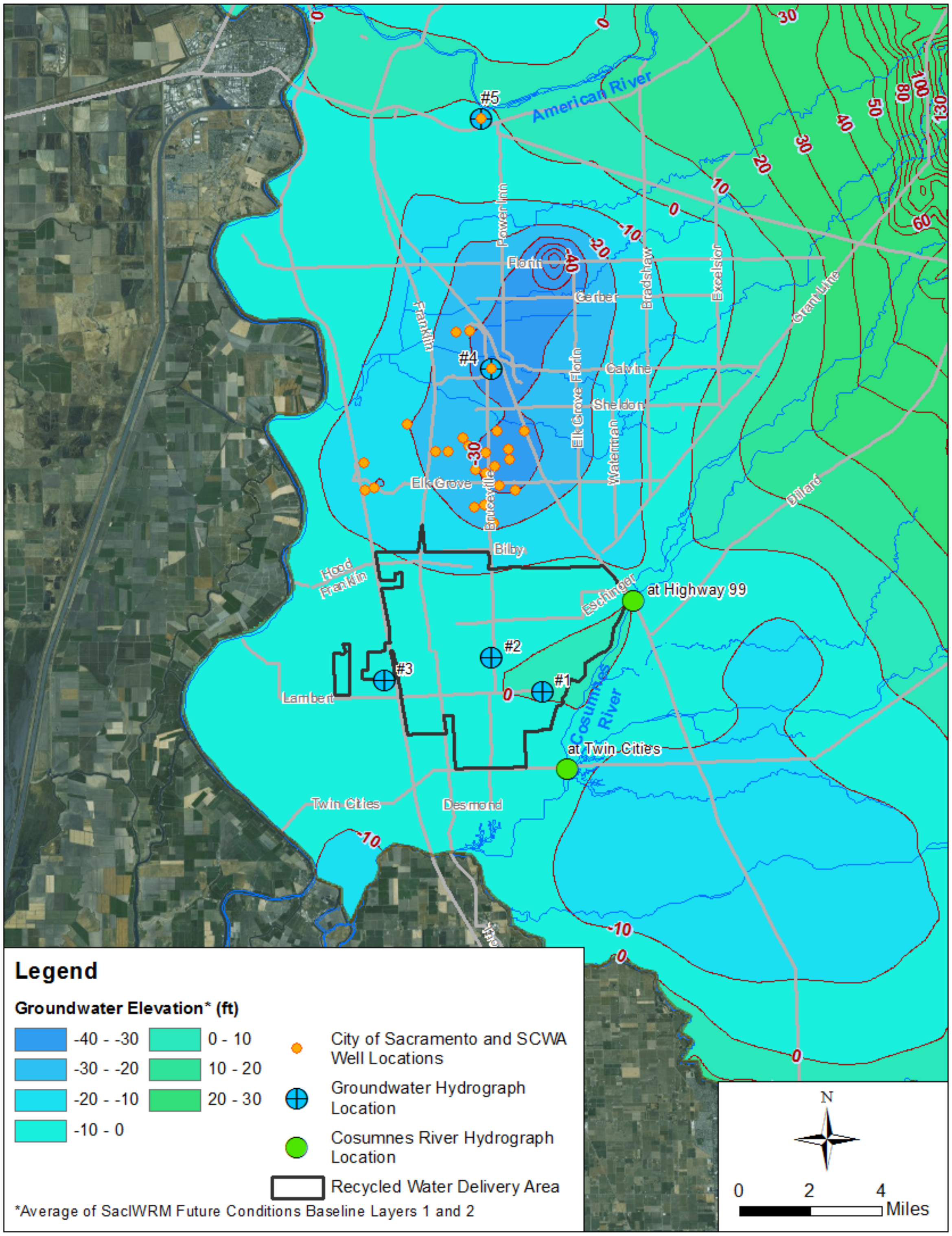


Figure 44: Groundwater Elevation, Dry Year (Fall 1994, 67th Year of Simulation), Project 2030

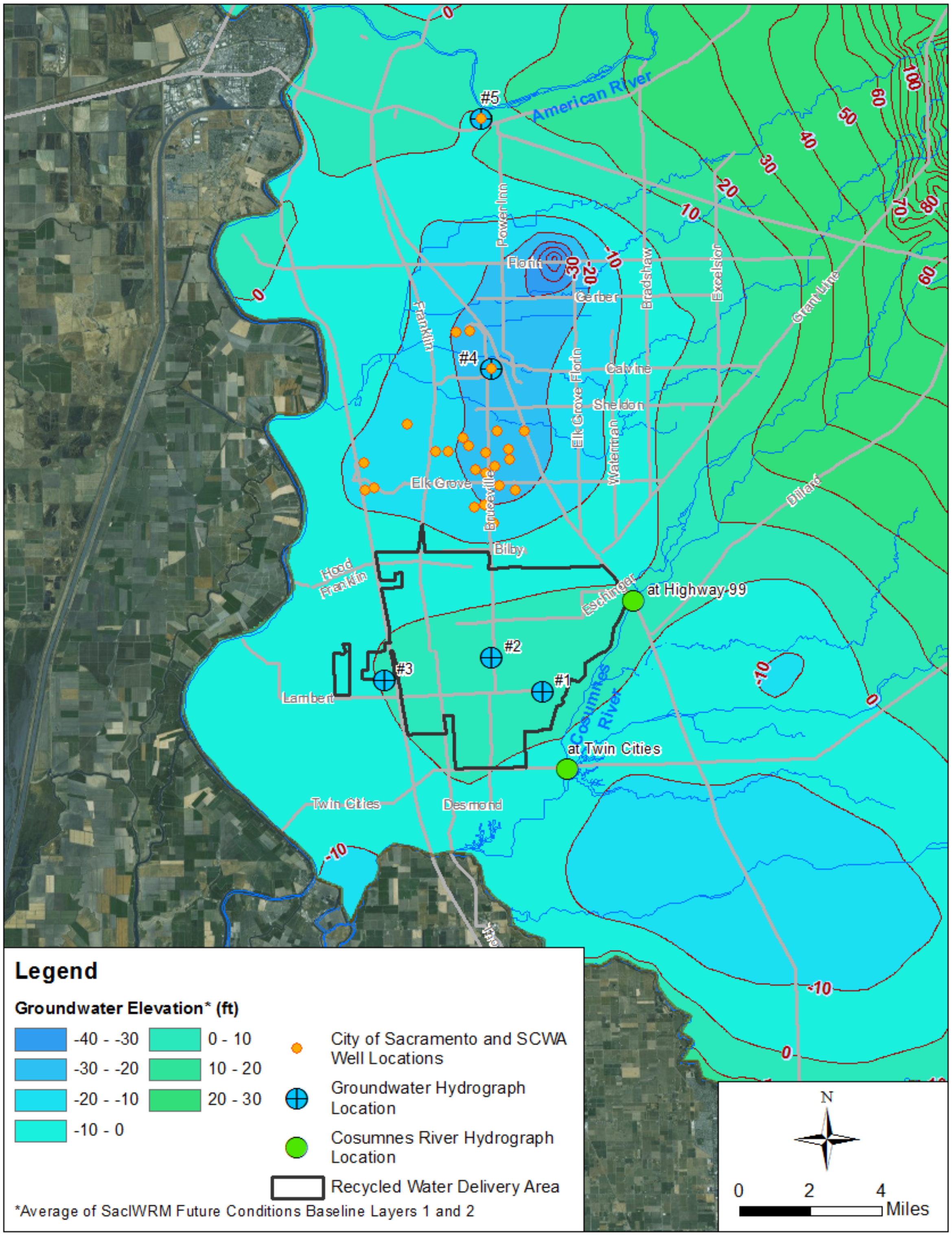


Figure 45: Groundwater Elevation, Normal Year (Fall 2004, 77th Year of Simulation), Project 2030

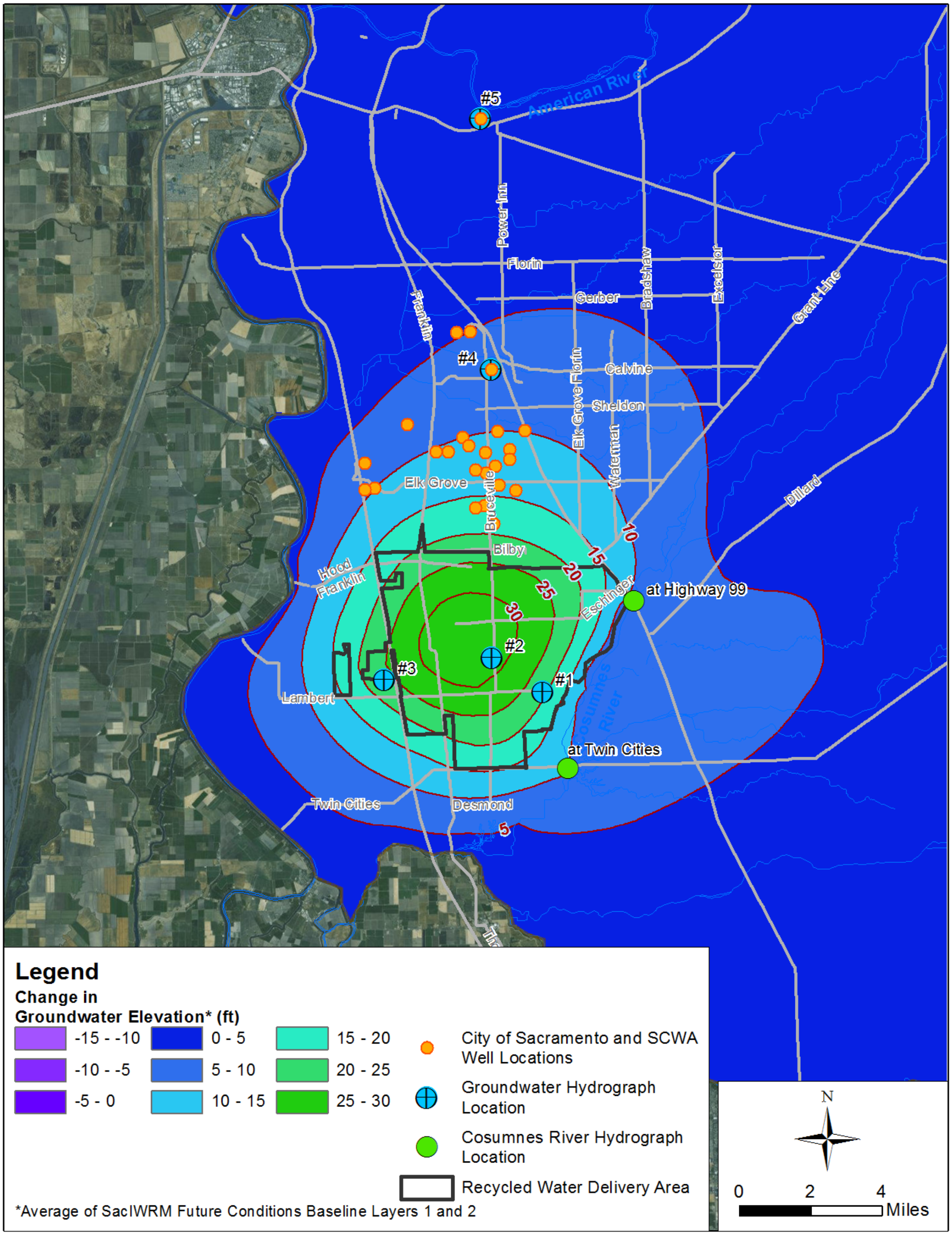


Figure 46: Change in Groundwater Elevation, Wet Year (Fall 1984, 57th Year of Simulation), Project 2030

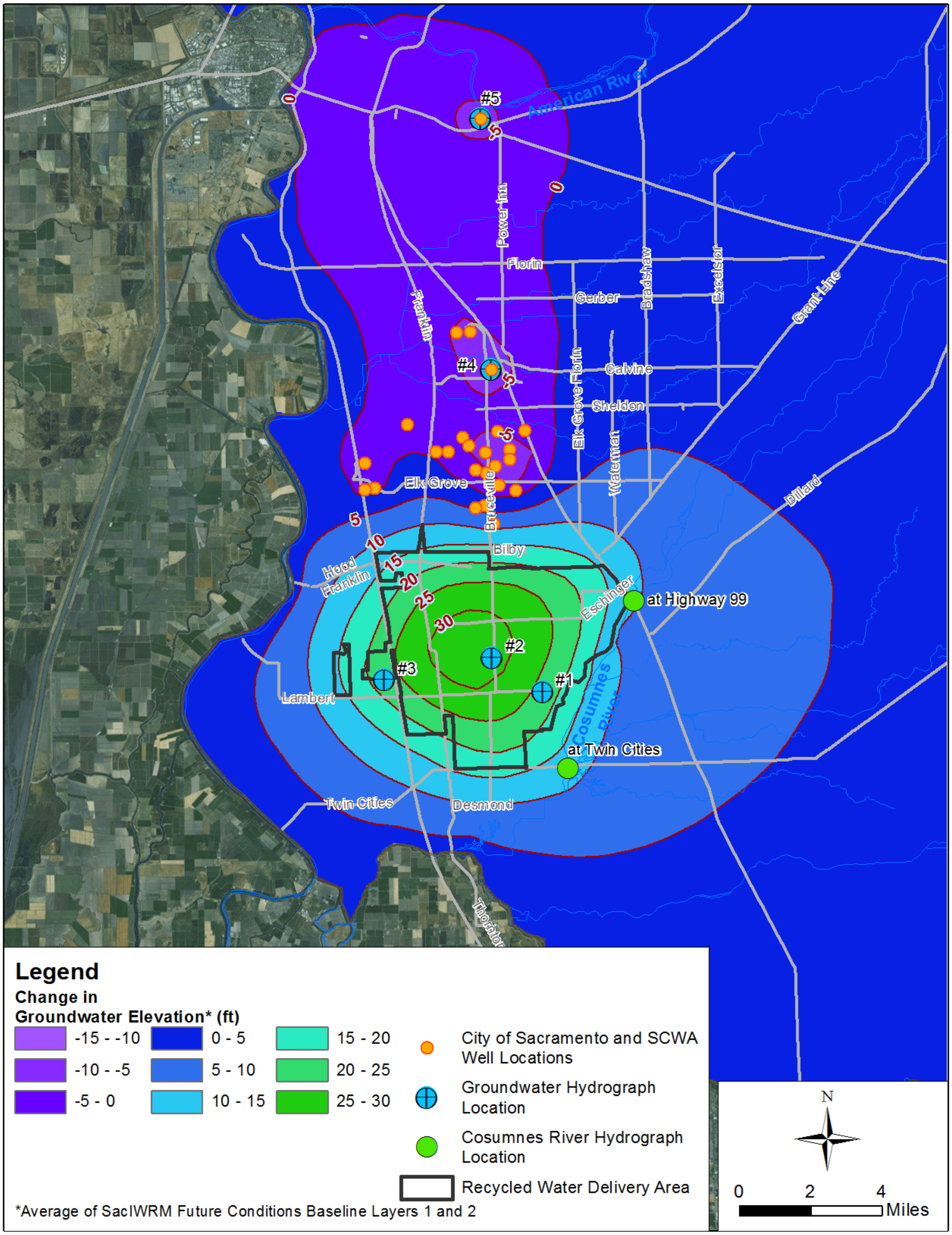


Figure 47: Change in Groundwater Elevation, Dry Year (Fall 1994, 67th Year of Simulation), Project 2030

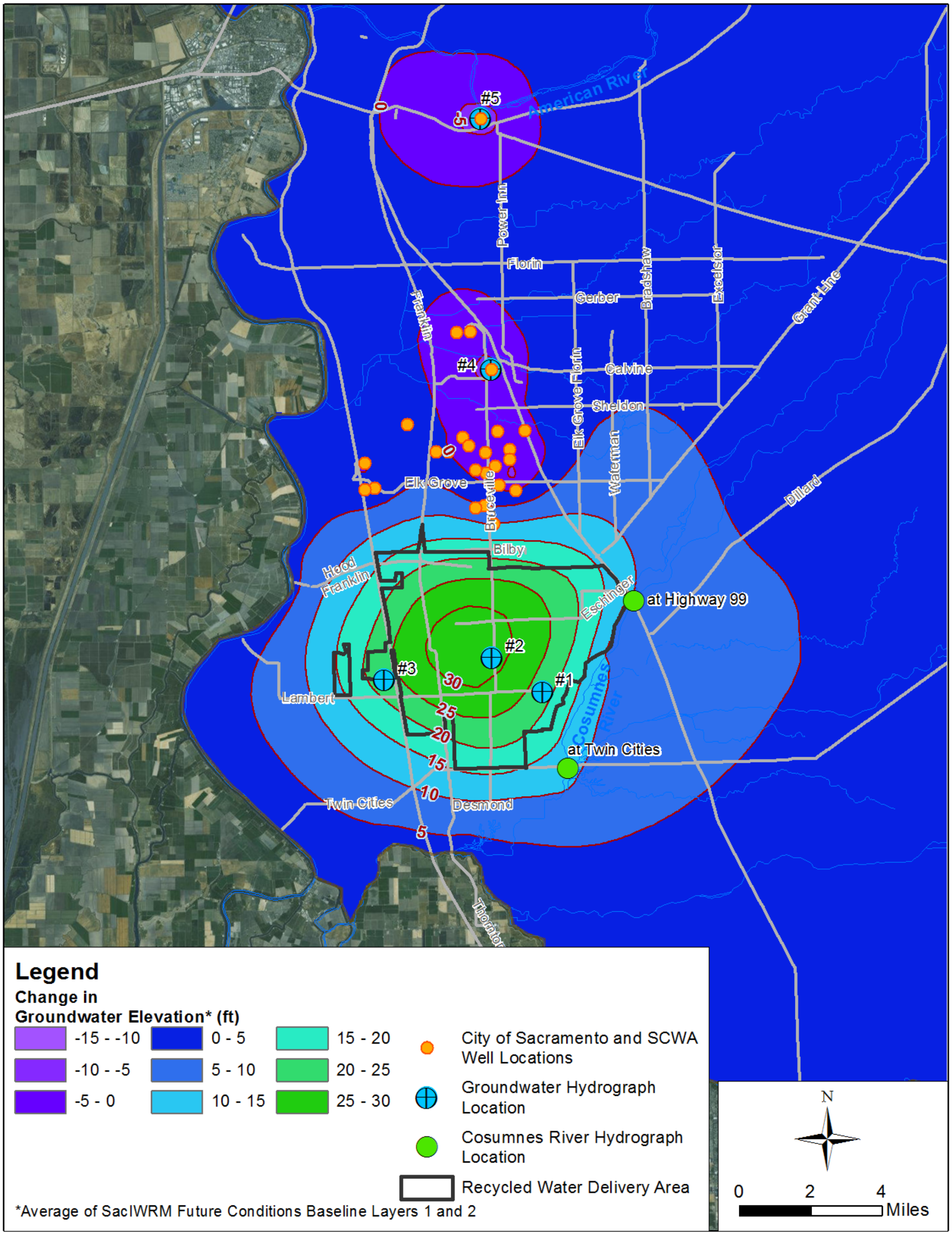


Figure 48: Change in Groundwater Elevation, Normal Year (Fall 2004, 77th Year of Simulation), Project 2030

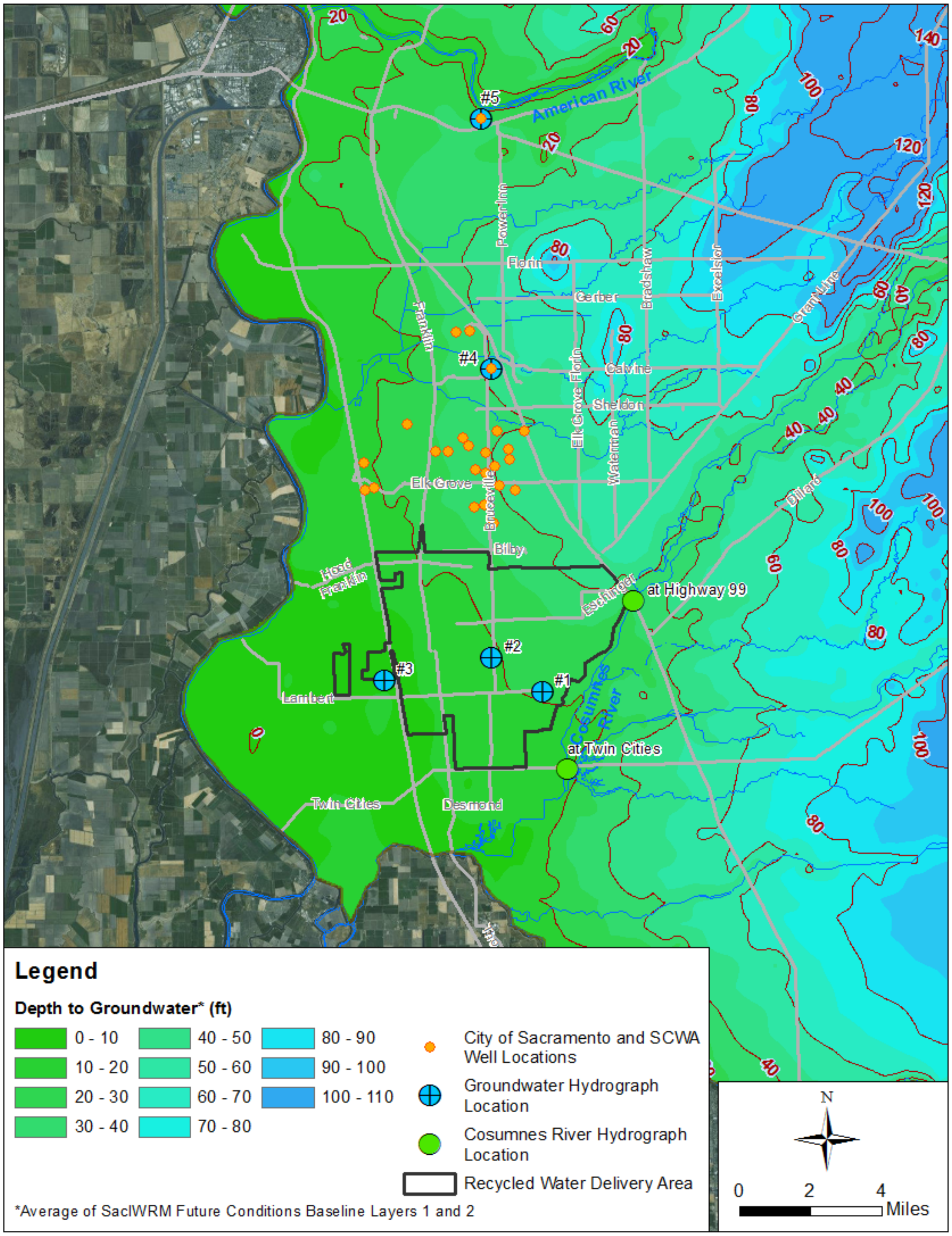


Figure 49: Depth to Groundwater, Wet Year (Fall 1984, 57th Year of Simulation), Project 2030

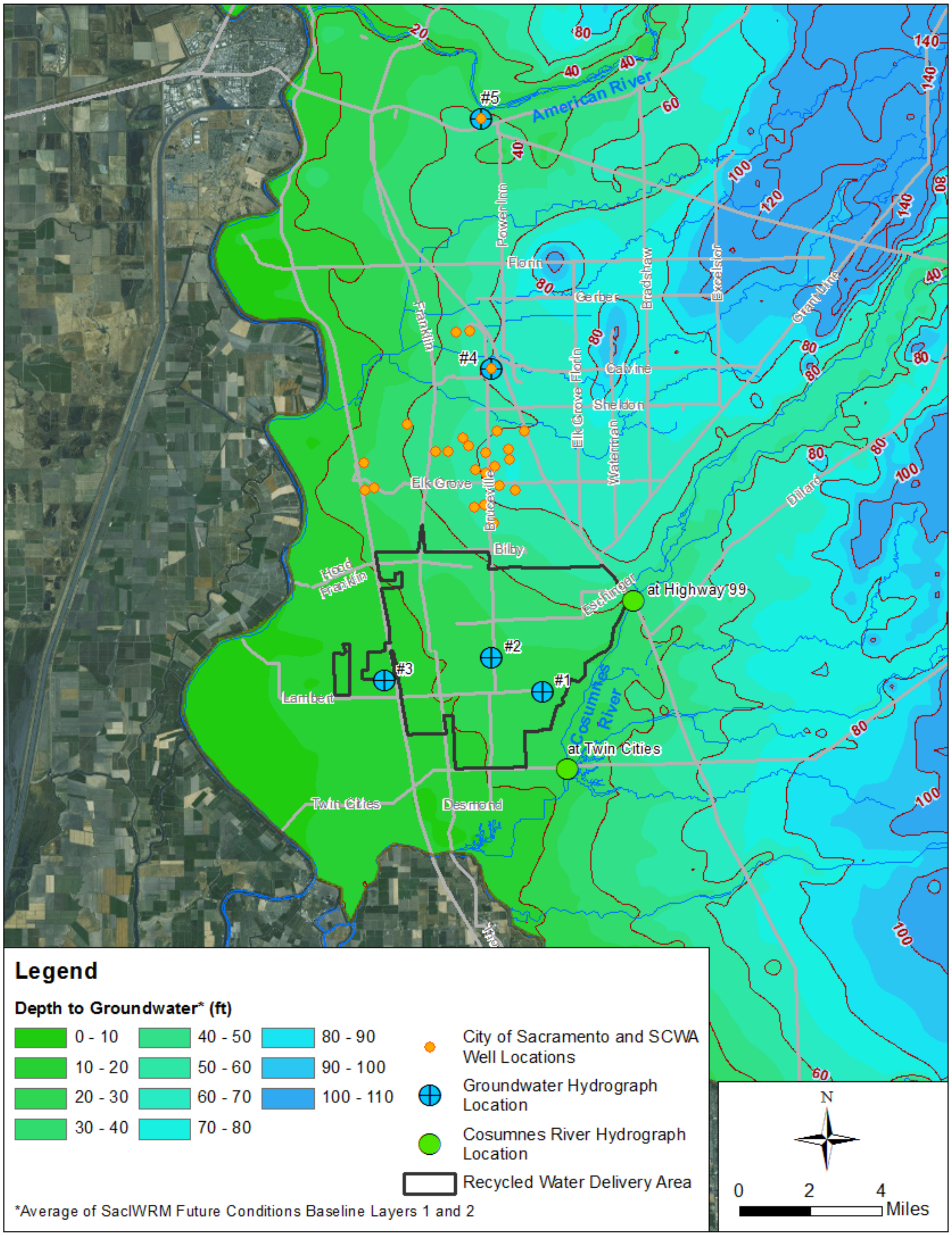


Figure 50: Depth to Groundwater, Dry Year (Fall 1994, 67th Year of Simulation), Project 2030

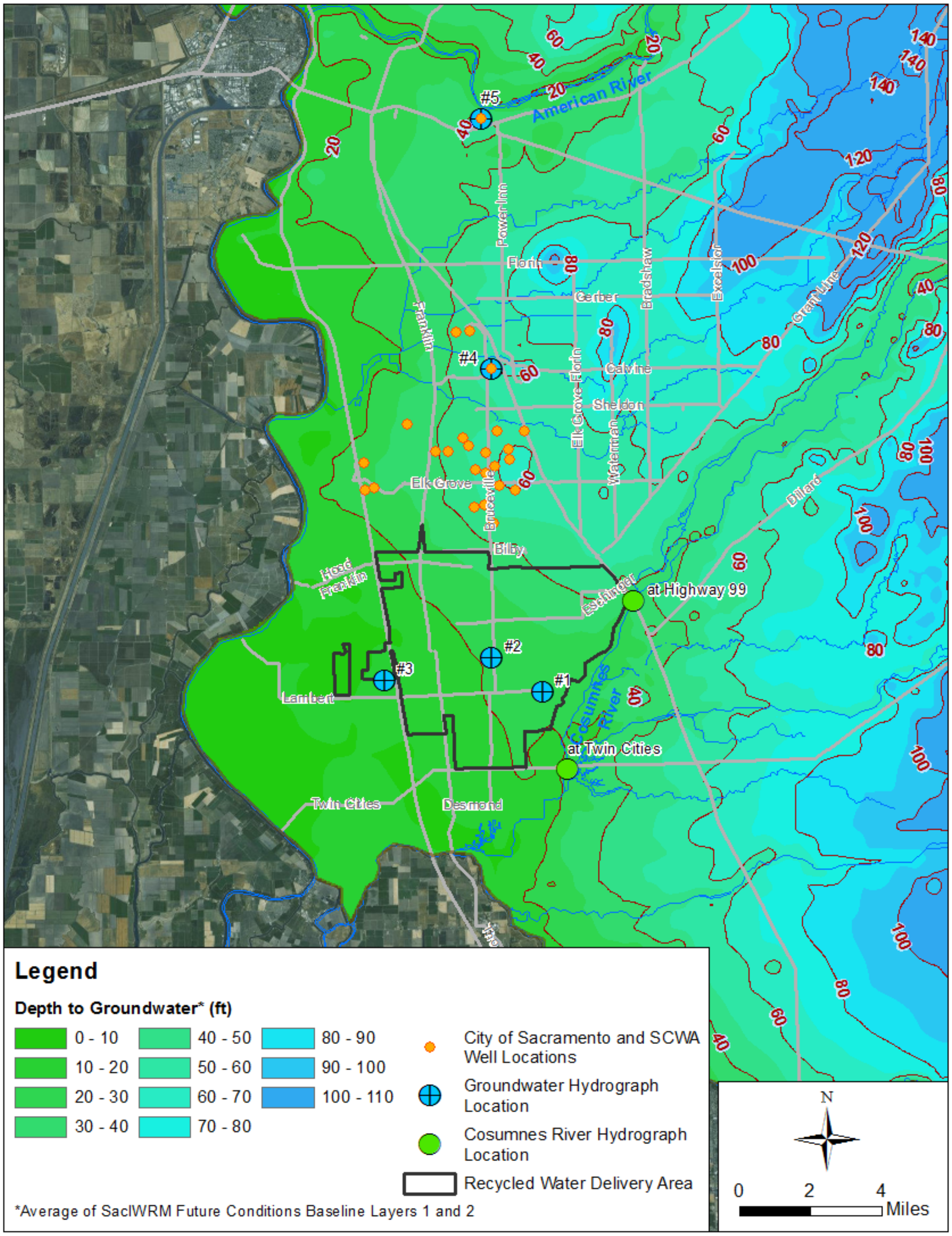
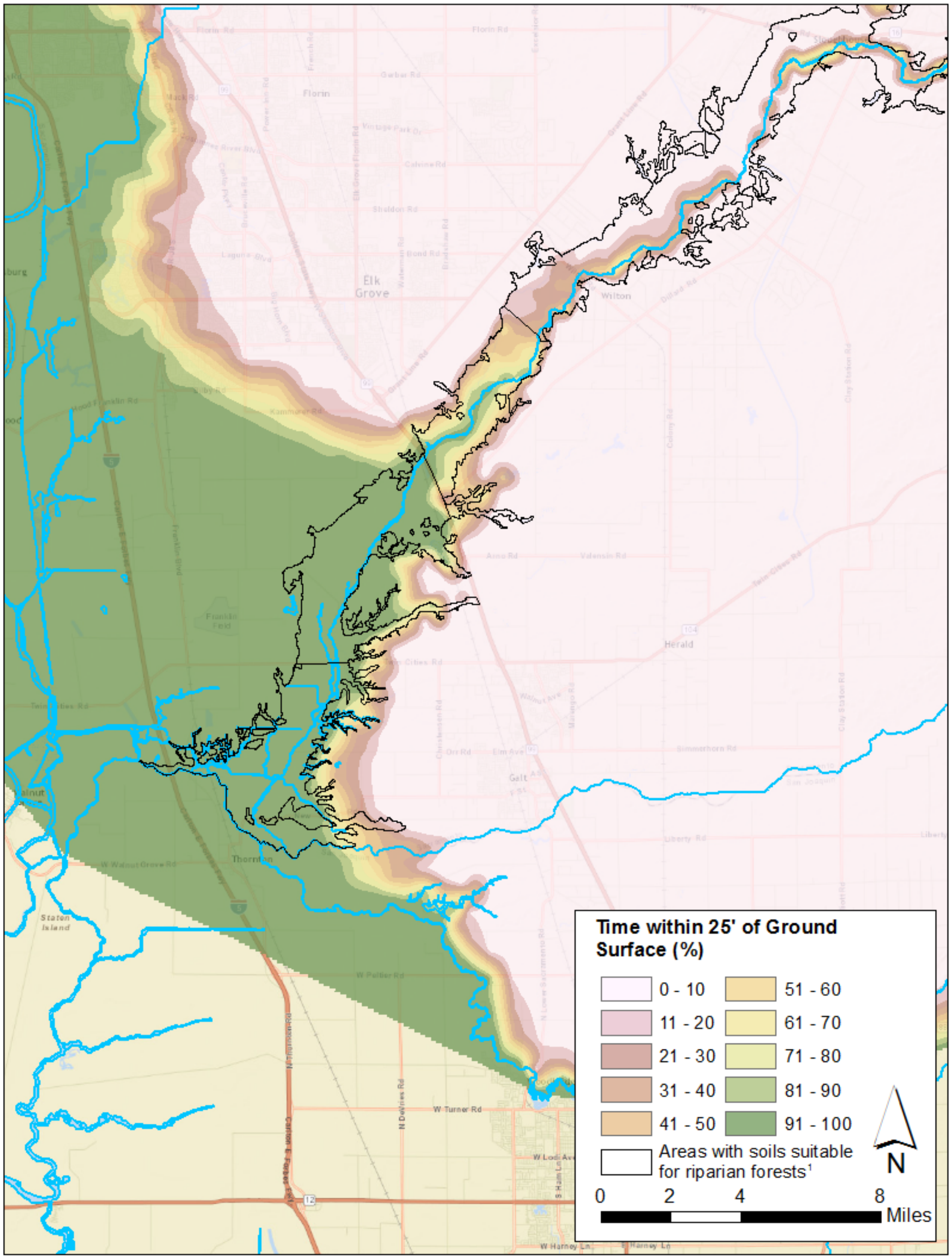


Figure 51: Depth to Groundwater, Normal Year (Fall 2004, 77th Year of Simulation), Project 2030



1. Source TNC 2014

Figure 52: Percent of Time Groundwater Levels are within 25 feet of the Ground Surface, Project 2030

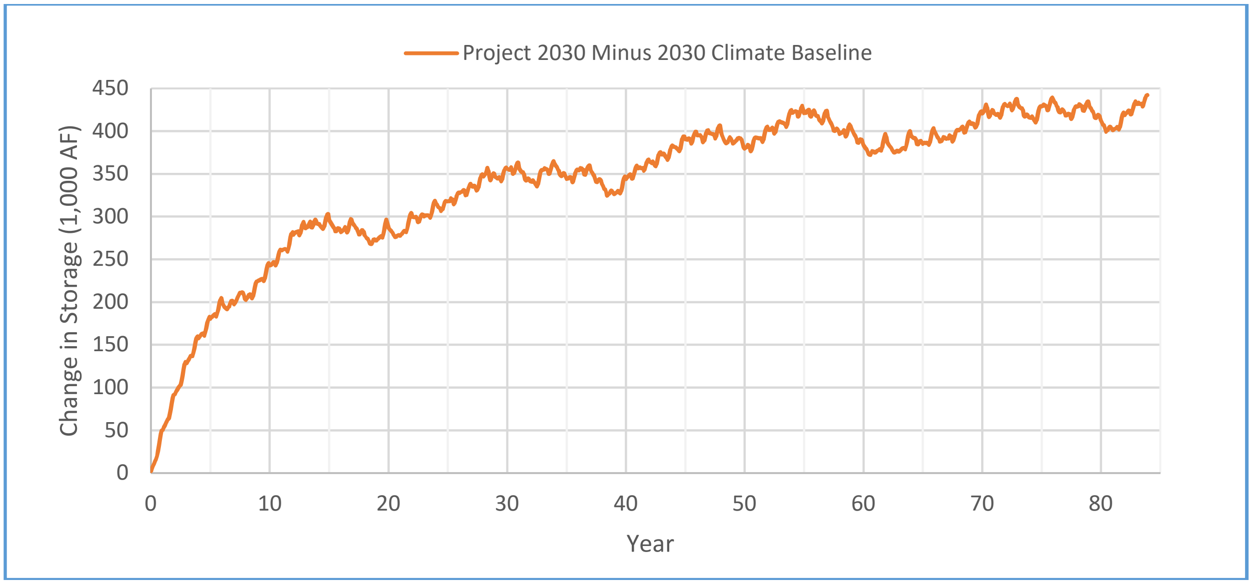


Figure 53: Change in Groundwater Volume, Project 2030 Compared to 2030 Climate Baseline

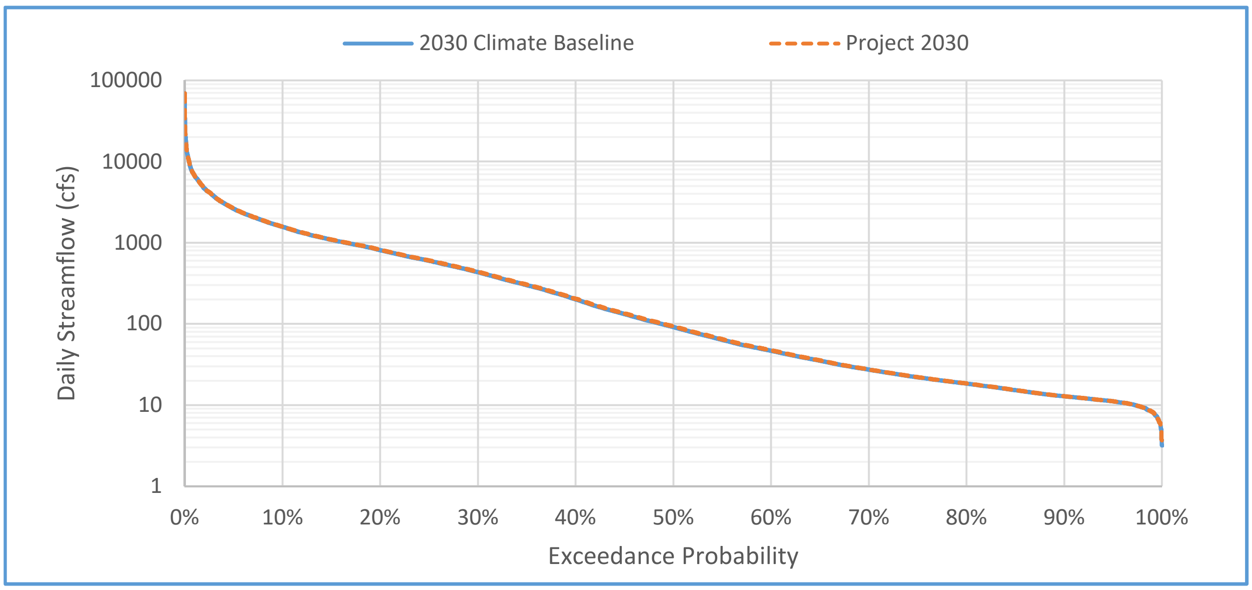


Figure 54: Streamflow Exceedance Chart at Cosumnes River at Highway 99 (McConnell Gage), Project 2030

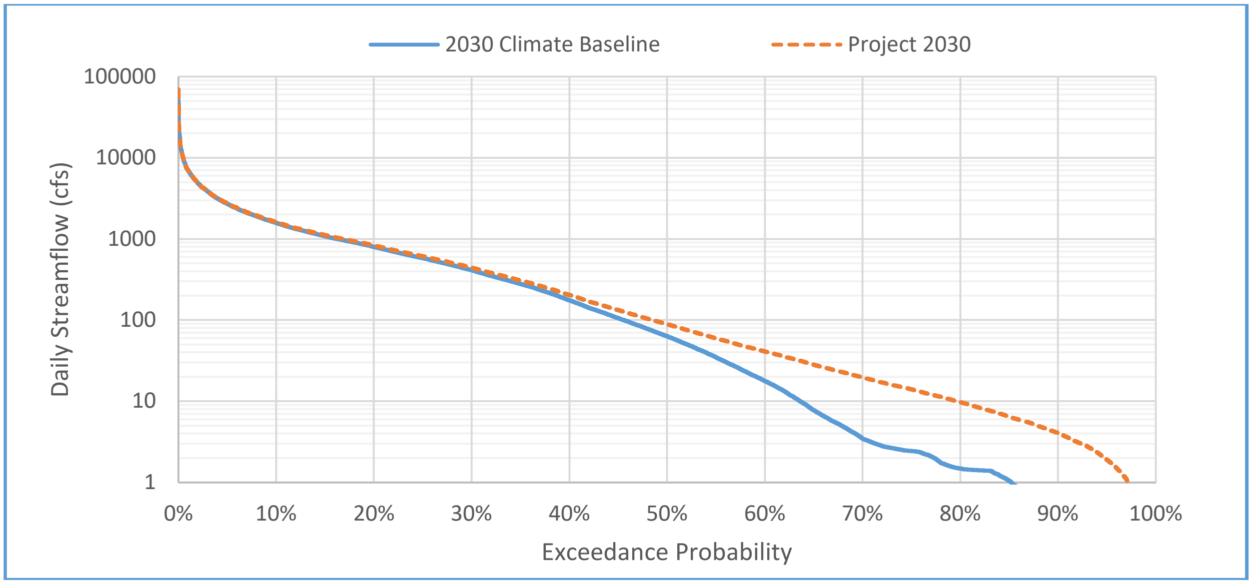


Figure 55: Streamflow Exceedance Chart at Cosumnes River at Twin Cities Road, Project 2030

Table 1: Water Supplies within Project Area, Project 2030

Month	Groundwater Demand (AF/Month)		Surface Water Demand (AF/Month)		Recycled Water Demand (AF/Month)		Total (AF/Month)	
	2030 Climate Baseline	Project 2030	2030 Climate Baseline	Project 2030	2030 Climate Baseline	Project 2030	2030 Climate Baseline	Project 2030
Jan	0	0	0	0	0	3,600	0	3,600
Feb	0	0	0	0	0	3,600	0	3,600
Mar	100	0	0	0	0	3,700	100	3,700
Apr	2,200	100	0	0	0	2,100	2,200	2,200
May	8,400	2,400	0	0	0	6,000	8,400	8,400
June	9,700	3,400	0	0	0	6,300	9,700	9,700
July	11,300	5,000	0	0	0	6,300	11,300	11,300
Aug	7,500	1,200	0	0	0	6,400	7,500	7,600
Sept	4,000	100	0	0	0	3,800	4,000	3,900
Oct	1,100	0	0	0	0	1,000	1,100	1,000
Nov	0	0	0	0	0	3,600	0	3,600
Dec	0	0	0	0	0	3,600	0	3,600
Total	**44,300**	**12,200**	**0**	**0**	**0**	**50,000**	**44,300**	**62,200**

Table 2: Groundwater Storage, Inflows, and Outflows Compared to the 2030 Climate Baseline, Project 2030

Project 2030 Minus 2030 Climate Baseline	Impact on Water Budget for the Entire Model Area (AFY)						
	Groundwater Production	Recharge	Gain from Rivers/Streams	Boundary Inflow	Change in Groundwater Storage	Other	Stream Outflow
Full Simulation	-23,000	17,900	-20,700	-15,000	5,300	100	31,800
First Half	-23,200	17,900	-18,700	-13,900	8,700	200	29,400
Second Half	-22,700	17,900	-22,800	-16,000	1,800	0	34,300

4.2 Project 2070 Scenario

Similar to the Project 2030 Scenario, Project 2070 Scenario with the 2070 climate conditions results in an increase in groundwater elevations in and near the project area. This increase in groundwater elevations results in reduced recharge from surface water courses, particularly from the Cosumnes River. Additionally, inflows from surrounding basins are reduced, particularly from the Solano Subbasin in Yolo County and the Eastern San Joaquin Subbasin to the south of the Mokelumne River.

The results of Project 2070 Scenario with the 2070 climate conditions are summarized in the following figures:

- Groundwater hydrographs at three locations, shown on Figure 56~~Figure 56~~
  - Hydrograph for Location 1: Figure 57~~Figure 57~~
  - Hydrograph for Location 2: Figure 58~~Figure 58~~
  - Hydrograph for Location 3: Figure 59~~Figure 59~~
  - Hydrograph for Location 4: Figure 60~~Figure 60~~
  - Hydrograph for Location 5: Figure 61~~Figure 61~~
- Groundwater elevation maps for three selected dates, representing different hydrologic conditions
  - Wet (fall 1984): Figure 62~~Figure 62~~
  - Dry (fall 1994): Figure 63~~Figure 63~~
  - Normal (fall 2004): Figure 64~~Figure 64~~
- Change in groundwater elevation maps for three selected dates, representing different hydrologic conditions
  - Wet (fall 1984): Figure 65~~Figure 65~~
  - Dry (fall 1994): Figure 66~~Figure 66~~
  - Normal (fall 2004): Figure 67~~Figure 67~~
- Depth to groundwater maps for three selected dates, representing different hydrologic conditions
  - Wet (fall 1984): Figure 68~~Figure 68~~

    - Dry (fall 1994): Figure 69~~Figure 69~~
    - Normal (fall 2004): Figure 70~~Figure 70~~
- Percent of time groundwater levels are within 25 feet of the ground surface: Figure 71~~Figure 71~~
- Time series chart of change in groundwater volume, compared to the 2070 Climate Baseline: Figure 72~~Figure 72~~
- Streamflow exceedance charts at two locations, shown on Figure 56~~Figure 56~~
    - Cosumnes River at Highway 99 (McConnell gage): Figure 73~~Figure 73~~
    - Cosumnes River at Twin Cities Road: Figure 74~~Figure 74~~
- Table of groundwater storage, inflows, and outflows, compared to the 2030 Climate Baseline: Table 4

Similar to the Project 2030 Scenario, Project 2070 Scenario simulates reduction of recycled water deliveries to the in-lieu service area during the dry periods when the Lake Shasta storage falls below a threshold. However, this occurs in four years under the 42-year hydrology (1970-2011) in the 2070 climate conditions compared to a single occurrence under the 2030 Climate Baseline. While the in-lieu recharge benefits are slightly reduced, the wintertime irrigation is increased to make up for the difference and to maintain the project recharge capacity at 50,000 AFY.

The groundwater hydrographs show how groundwater elevations change under the 2070 Climate Baseline and the Project 2070 Scenario. Groundwater elevations increase due to the project approximately 30 feet after 15 years near the center of the project at hydrograph location 2 (Figure 58~~Figure 58~~, with location shown in Figure 56~~Figure 56~~), generally stabilizing at a long-term increase of approximately 35 feet. Groundwater elevation increases are smaller towards the boundaries of the project area, with hydrograph location 1 (Figure 57~~Figure 57~~) and hydrograph location 3 (Figure 59~~Figure 59~~) showing long-term project-related increases in groundwater elevation of approximately 25 feet at locations 1 and 30 feet at location 2.

Extraction of up to 30 percent of the banked water results in lowered groundwater elevations near and around the extraction wells used for the project banked water extraction. Groundwater levels decrease during extraction years and recover to remain above the 2070 Climate Baseline during non-extraction years as a result of the ongoing in-lieu recharge and wintertime irrigation. At the end of the 84 years of the simulation, groundwater levels remain above the 2070 Climate Baseline at location 4 (Figure 60~~Figure 60~~) and at approximately the same level at location 5 (Figure 61~~Figure 61~~).

Groundwater flow direction is shown through groundwater elevation maps. Comparison of groundwater elevation maps from the Project 2070 Scenario (Figure 62~~Figure 62~~ - Figure 64~~Figure 64~~) to those from the 2070 Baseline (Figure 22~~Figure 22~~ - Figure 24~~Figure 24~~) shows that groundwater elevations rise in the project area and gradients change, the general flow direction remains from the Cosumnes River towards regional pumping depressions in the Elk Grove area and toward the extraction wells assumed to extract the project banked water.

Change in groundwater elevation maps emphasize where groundwater elevations increase as a result of the project. As described above, groundwater elevations increase most in the center of the project area, up to approximately 35 feet compared to the 2030 Baseline (Figure 65~~Figure 65~~ - Figure 67~~Figure 67~~). The area with at least 15-20 feet increase in groundwater elevations extends to just beyond the project boundaries. Compared to the Project 2030 Climate conditions, hydrologic conditions have a greater impact on the project-related increases in groundwater elevation, with larger increases compared to the 2070 Baseline during dry periods as opposed to wetter periods. During the wet periods, the overall increase in groundwater elevations spread over larger areas well beyond the project area compared to the normal and dry periods. Overall, the increase in groundwater elevations during each water year type is greater for the Project 2070 Scenario (Figure 65~~Figure 65~~ - Figure 67~~Figure 67~~) than the Project 2030 Scenario (Figure 46~~Figure 46~~ - Figure 48~~Figure 48~~). Extraction of the project banked water results in lowered groundwater elevations near and around the extraction wells used for extraction of the banked water during the extraction years. Overall, the drawdown is mainly at and near the extraction wells during normal year and dry years with less to no decline in groundwater levels away from the wells and further away from the project area. Overall, the groundwater extraction in areas further away from the project area would have less impacts on the overall project benefits gained from the groundwater recharge.

Depth to groundwater maps provide information on the lift required to pump groundwater and on the overall ability for wells to pump water. The depth to groundwater in the Project Area improves due to the in-lieu recharge (Figure 68~~Figure 68~~ - Figure 70~~Figure 70~~) compared to depths under the 2070 Climate Baseline conditions (Figure 25~~Figure 25~~ - Figure 27~~Figure 27~~). Depths to groundwater decrease to a minimum of approximately 15-20 feet near the southwestern portion of the Project Area. Near the Cosumnes River, depths to groundwater decrease to a minimum of approximately 20-60 feet below ground surface, depending on water year types, with greater depth to groundwater during dry years.

Similar to the depth maps, potential benefits to riparian forests are summarized by showing the percentage of time groundwater levels would be within 25 feet of the surface[5] (Figure 71~~Figure 71~~). For the Project 2070 Climate conditions, approximately 13,200 acres meets the riparian threshold of groundwater elevations within 25 feet of the surface 90 percent of the time, mostly focused in the areas of the Cosumnes River south of Highway 99. This is considerably higher than the 4,800 acres meeting the threshold under the 2070 Climate Baseline and lower than the 15,500 acres in the Project 2030 Scenario. In comparison, the area under the Project 2070 Scenario that meets the riparian threshold extends further to the northeast from the Highway 99 crossing of the Cosumnes River.

[5] As this figure focuses on shallow groundwater conditions, the information presented here represents conditions in Layer 1 of the SacIWRM, while previous figures represent an average of Layer 1 and Layer 2.

Figure 72~~Figure 72~~ shows how storage increases in the basin as a result of the project by comparing the Project 2070 Scenario to the 2070 Climate Baseline. Similar to the Project 2030 Scenario, storage initially increases rapidly, as most of the initial in-lieu recharge and wintertime irrigation go to increase groundwater in storage. After 10 years, approximately 500,000 AF has been recharged (combined in-lieu recharge and wintertime irrigation), with an increase in groundwater in storage of approximately 256,000 AF and the remainder resulting in increased streamflows or increased storage in adjacent basins. This suggests approximately 50% of the recharged water results in increased storage over this time period. In the first 10 years, storage increases rapidly as most of the recharge accrues to groundwater storage. Subsequently, as groundwater levels rise, less of the recharge contributes to groundwater storage and more contributes to streamflows or storage in adjacent basins. The rate of increase in storage continues at a slower rate, as reflected in the increasing trends in the groundwater storage in Figure 72~~Figure 72~~. Based on the groundwater hydrographs, groundwater levels near the project area continue to increase in the first 15-20 years of the simulations, generally stabilizing thereafter. In the first 20 years of the simulation, 1,000,000 AF is recharged with an increase in groundwater storage of approximately 320,000 AF (or approximately 32% of the recharged water) under the Project 2070 Scenario. The majority of the change in storage would occur in the first 20 years of the simulation. As the higher groundwater elevations increasingly interact with rivers and adjacent groundwater basins, this results in reduced groundwater recharge from rivers and reduced inflow from surrounding basins compared to the 2070 Climate Baseline. Generally, over a very long time frame, for groundwater systems that reach an equilibrium, there would be no additional increase in storage, and the full recharge volume results in increases in streamflow, but such conditions are not reached within the 84-year simulation period, although they are approached. In the last 10-15 years of the simulation, storage increase becomes more stabilized. Over the final 10 years of simulation, 500,000 AF is recharged with an increase in groundwater in storage of approximately 36,000 AF, or 7% of the recharged water, and the remainder resulting in increased streamflows or increased storage in adjacent basins. The increase in groundwater storage is consistently higher in the Project 2070 Scenario as compared to the 2070 Climate Baseline. At the end of the simulation, increases in groundwater in storage reaches to approximately 590,000 AF under the Project 2070 Scenario (Figure 72) compared to approximately 450,000 AF under the Project 2030 Scenario (Figure 53~~Figure 53~~). The rate of increase for the Project 2030 Scenario and Project 2070 Scenario is similar in the first 10 years of the simulation and continues at a slightly higher rate in the Project 2070 Scenario for the remaining of the simulation.

Conceptually, the project operations under the Project 2030 and 2070 Scenarios are similar and both scenarios maintain the project recharge capacity of 50,000 AFY, but with some variations in the in-lieu recharge, resulting banked water, winter irrigation, and project extractions. The Project 2070 Scenario assumes higher winter irrigation due to higher reduction in the in-lieu recharge during dry periods and lower project extractions due to lower banked water compared to the Project 2030 Scenario. Both the Project 2030 and 2070 Scenarios would benefit the groundwater system and streamflows. Comparison of the Project 2030 and 2070 Scenario results suggest that the Project 2070 Scenario would result in higher change in groundwater storage and higher flows in the Cosumnes River during low-flow events compared to the Project 2030 Scenario with increased benefits to the groundwater system and streamflows.

The higher groundwater elevations discussed above are a result of the increased groundwater in storage caused by in-lieu recharge and wintertime irrigation. The in-lieu recharge is achieved by supplying recycled water to participating growers, allowing pumps in groundwater wells to be turned off. Water that would have been pumped out of the aquifer is left in the aquifer, resulting in additional water in storage when compared to the 2070 Climate Baseline.

Streamflow conditions are summarized in exceedance charts, which show the percentage of time that different daily streamflows are exceeded. The charts show that streamflows are higher during low-flow events under the Project 2070 Scenario at Twin Cities Road (Figure 74~~Figure 74~~, with location shown on Figure 56~~Figure 56~~), which can potentially benefit the riparian environment around the river. On an average, the daily streamflow would be approximately 17 cfs higher under the Project 2070 relative to the 2070 Climate Change Baseline. Under the Project 2070 Scenario, the streamflows that are equal or greater than the average of 17 cfs would occur during 17,400 days (or approximately 56 percent) of the simulation period. While there is negligible difference in flows in the Cosumnes River at Highway 99 (Figure 73~~Figure 73~~, with location shown on Figure 56~~Figure 56~~), the average daily streamflow would be approximately 0.4 cfs higher under the Project 2070 Scenario with flows that are equal or greater than the average of 0.4 cfs occurring during 7,950 days (or 25 percent) of the simulation period. The trends seen at these two locations is consistent with the change in groundwater elevation maps, which indicate higher groundwater elevations near the Cosumnes River generally downstream of Highway 99. These conditions result in less recharge from the Cosumnes River to groundwater and thus higher streamflows with benefits to streamflows, in particular during low-flow events.

Table 3 summarizes the water supply conditions in the project area on an average monthly basis for the Project 2070 and the 2070 Climate Baselines. The selected water budget components presented in Table 4 show increases in storage, decreases in recharge from rivers and streams, and decreases in inflows from surrounding subbasins. The relative contribution to storage compared to increased streamflow and decreased inflows from surrounding subbasins is much higher in the earlier years of the project, as discussed earlier. Likewise, in the later years of the project the relative contribution to increased streamflow and decreased inflows from surrounding subbasins is much higher than the relative contribution to storage. To provide information for this shift in benefits, the budget is presented for the full 84-year simulation as well as separately for the first half and second half in Table 4. The change in storage is estimated to be approximately 10,900 AFY in the first half of the simulation and reduces to 3,100 AFY in the second half of the simulation. This further illustrates the project benefits to the groundwater storage realized early on the simulation. On the other hand, the gain from rivers and streams and inflows from the surrounding boundaries to the basin would be reduced (shown by negative sign) under the Project 2070 Scenario and the reduction would be much higher in the second half of the simulation than the first half. Further reduction in the second half illustrates the shift in the project benefits to increased streamflows and surrounding subbasins in later years of the simulation.

Finally, increases in streamflow under the project conditions were provided for use in CalSim-II simulations that simulated the surface water conditions of the project under 2070 climate.

Figures and Tables: Project 2070 Scenario

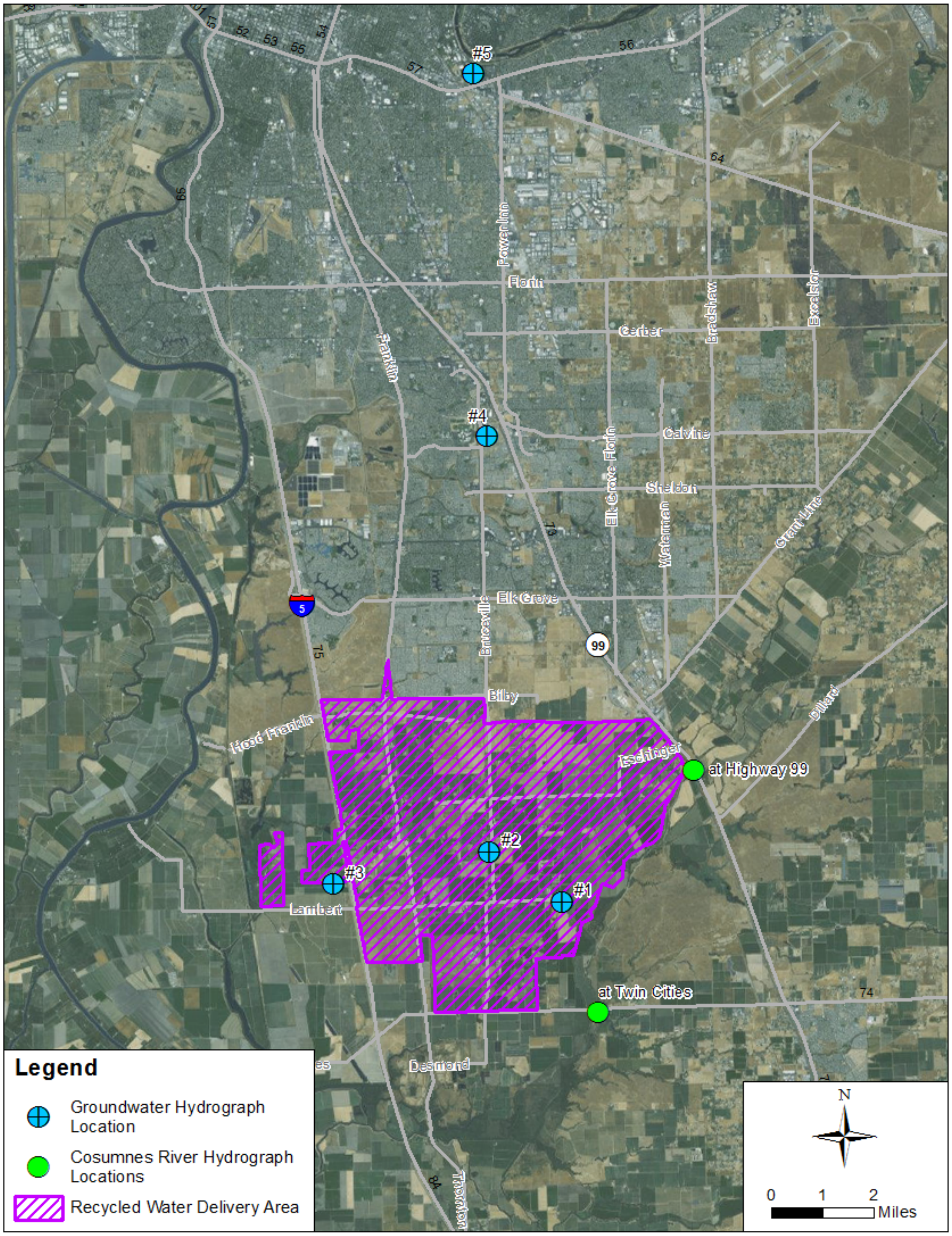


Figure 56: Project Location and Hydrograph Locations

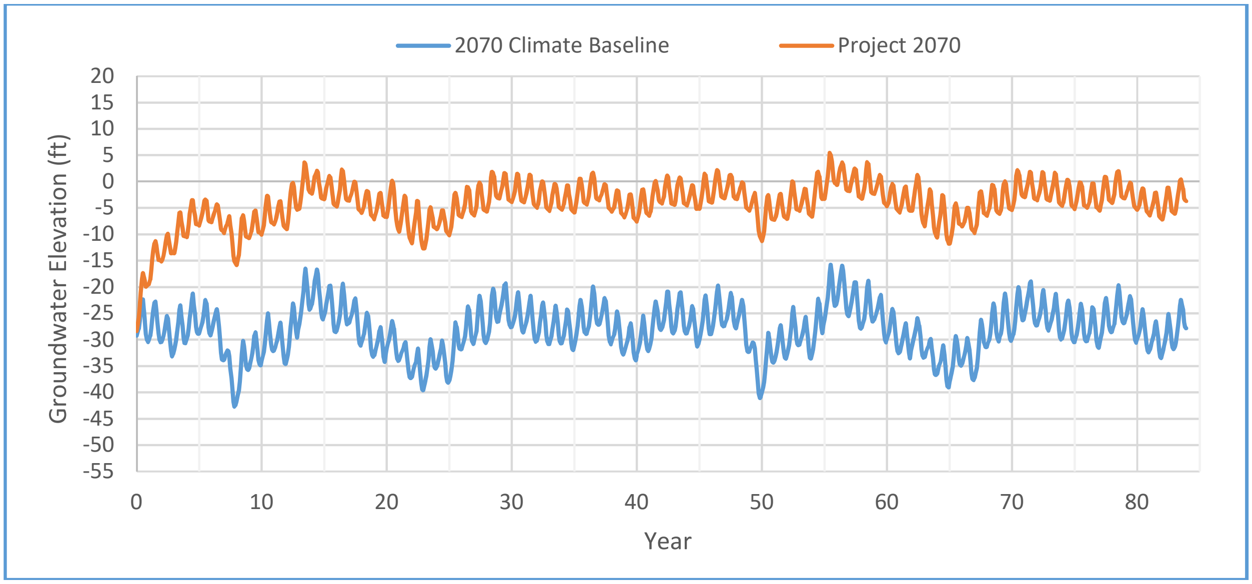


Figure 57: Groundwater Hydrograph at Location 1, Project 2070, Showing Response to Project Recharge near the Center of the Project Area

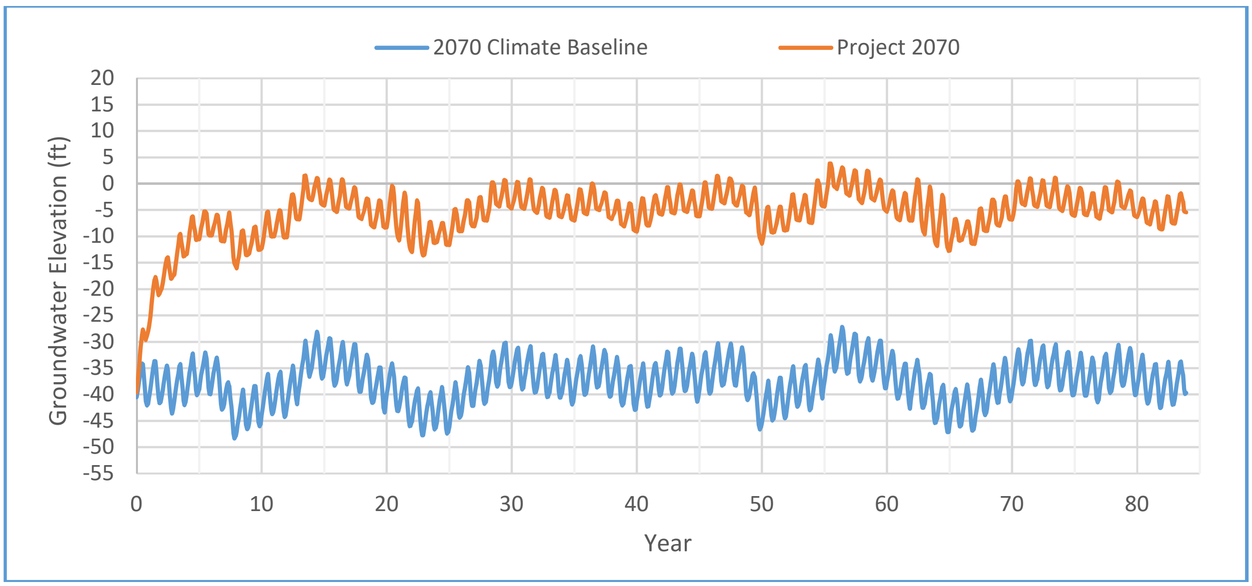


Figure 58: Groundwater Hydrograph at Location 2, Project 2070, Showing Response to Project Recharge at the Center of the Project Area

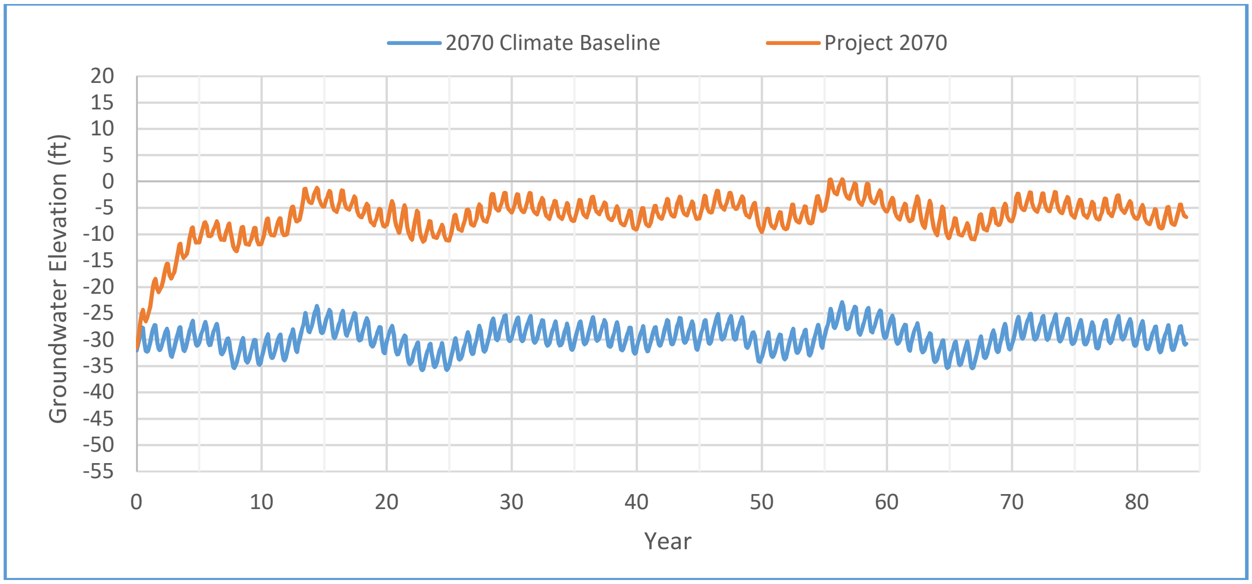


Figure 59: Groundwater Hydrograph at Location 3, Project 2070, Showing Response to Project Recharge near the Project Boundary

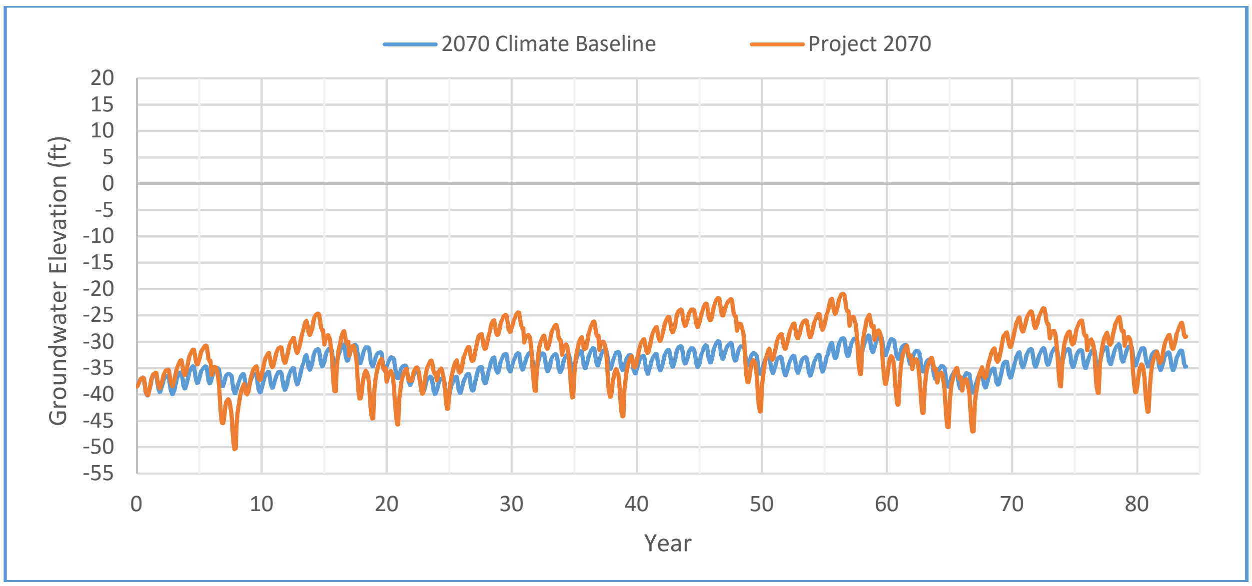


Figure 60: Groundwater Hydrograph at Location 4, Project 2070, Showing Response to Project Extraction near Extraction Wells

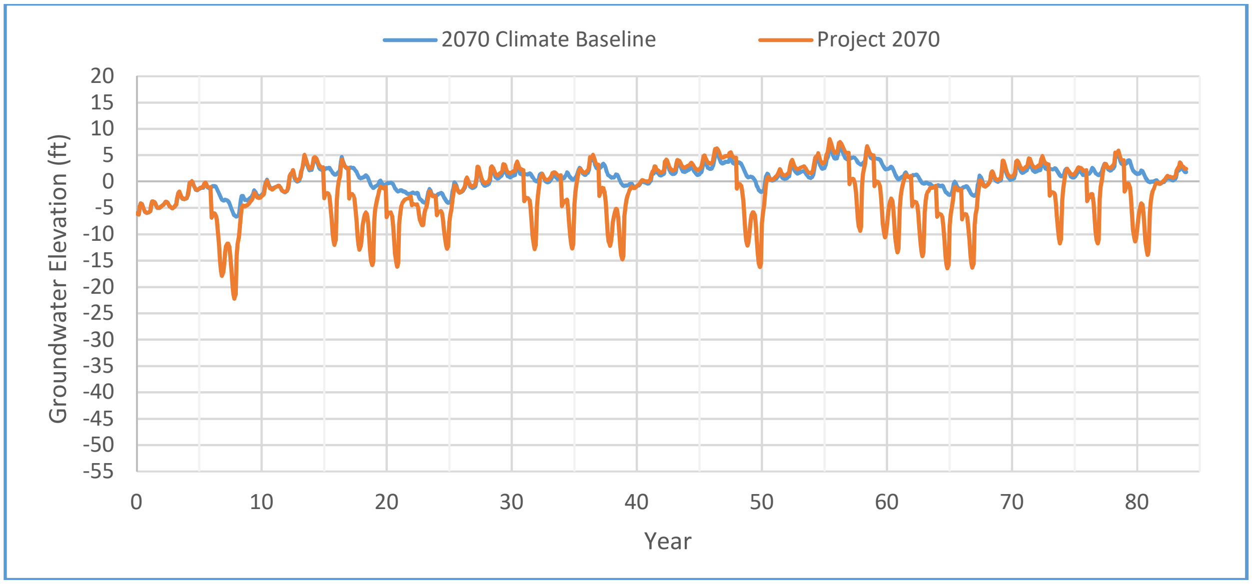


Figure 61: Groundwater Hydrograph at Location 5, Project 2070, Showing Response to Project Extraction near Extraction Wells

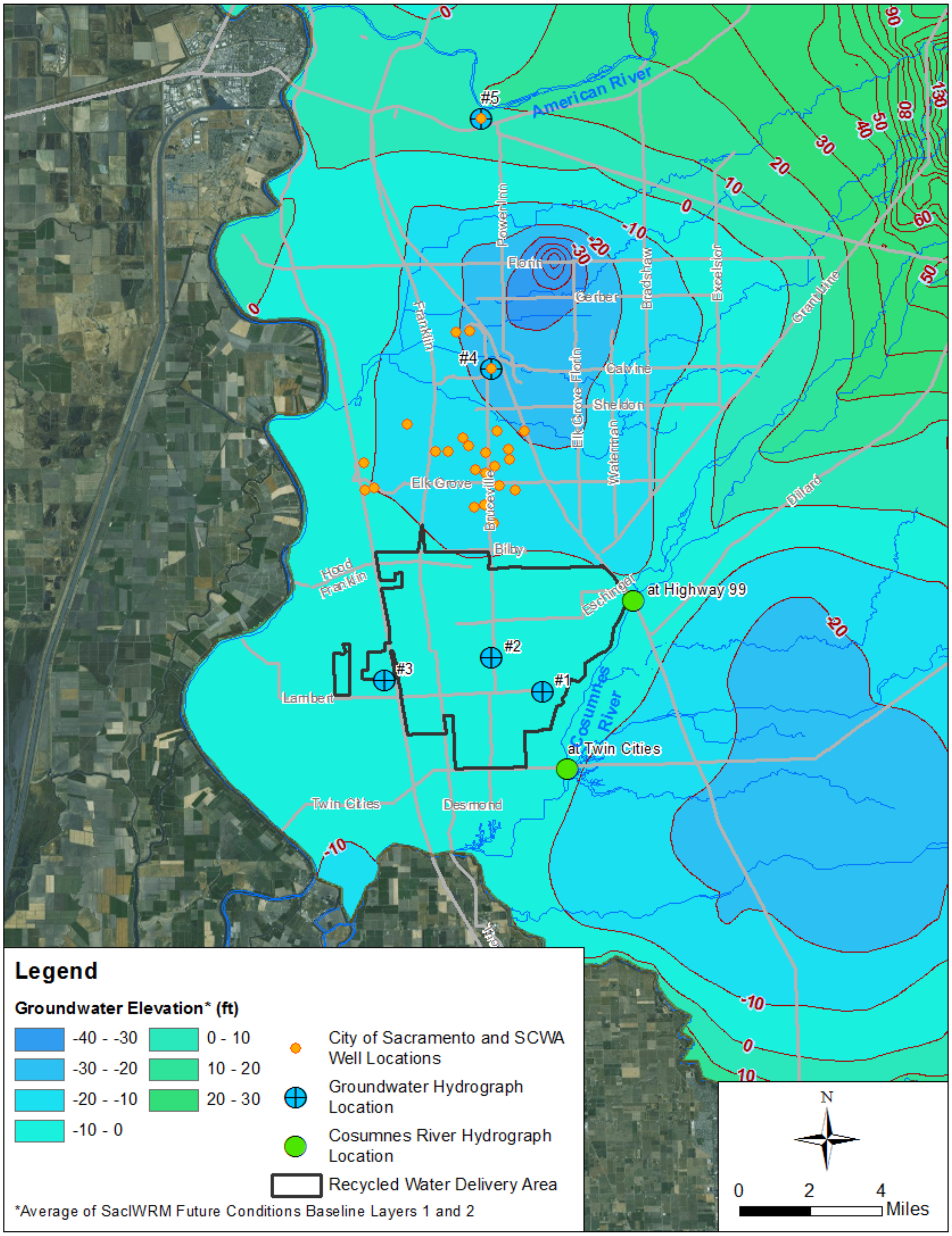


Figure 62: Groundwater Elevation, Wet Year (Fall 1984, 57th Year of Simulation), Project 2070

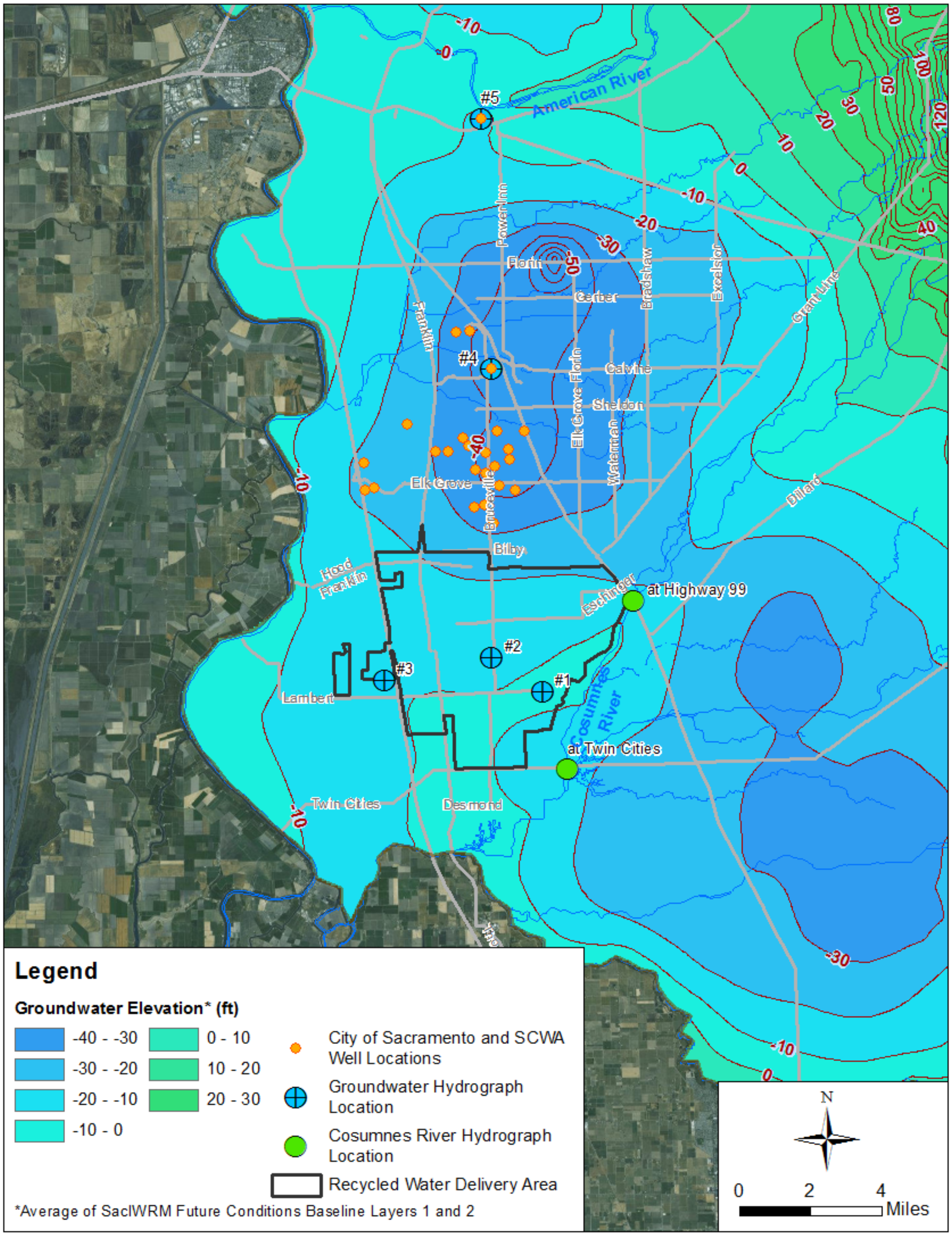


Figure 63: Groundwater Elevation, Dry Year (Fall 1994, 67th Year of Simulation), Project 2070

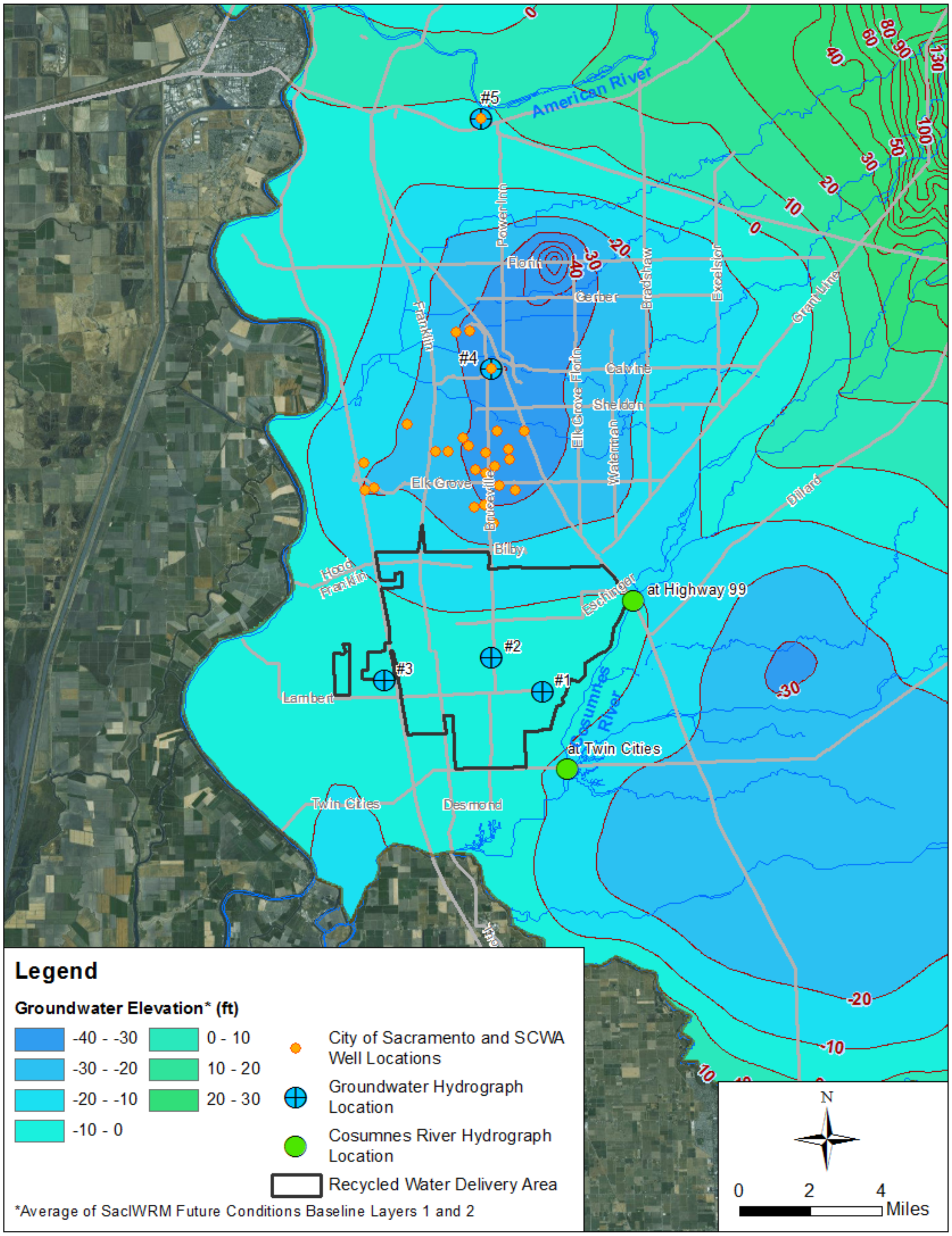


Figure 64: Groundwater Elevation, Normal Year (Fall 2004, 77th Year of Simulation), Project 2070

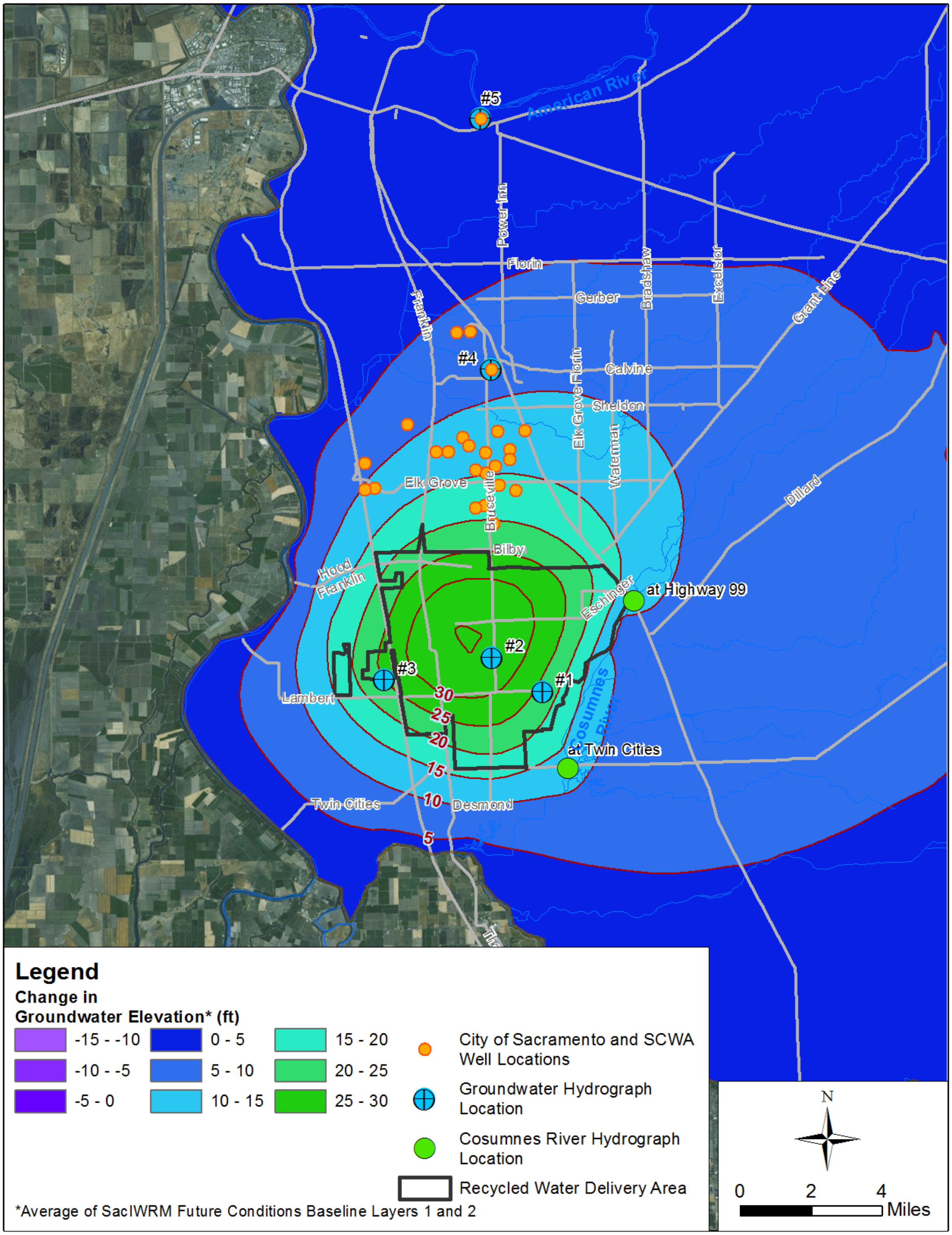


Figure 65: Change in Groundwater Elevation, Wet Year (Fall 1984, 57th Year of Simulation), Project 2070

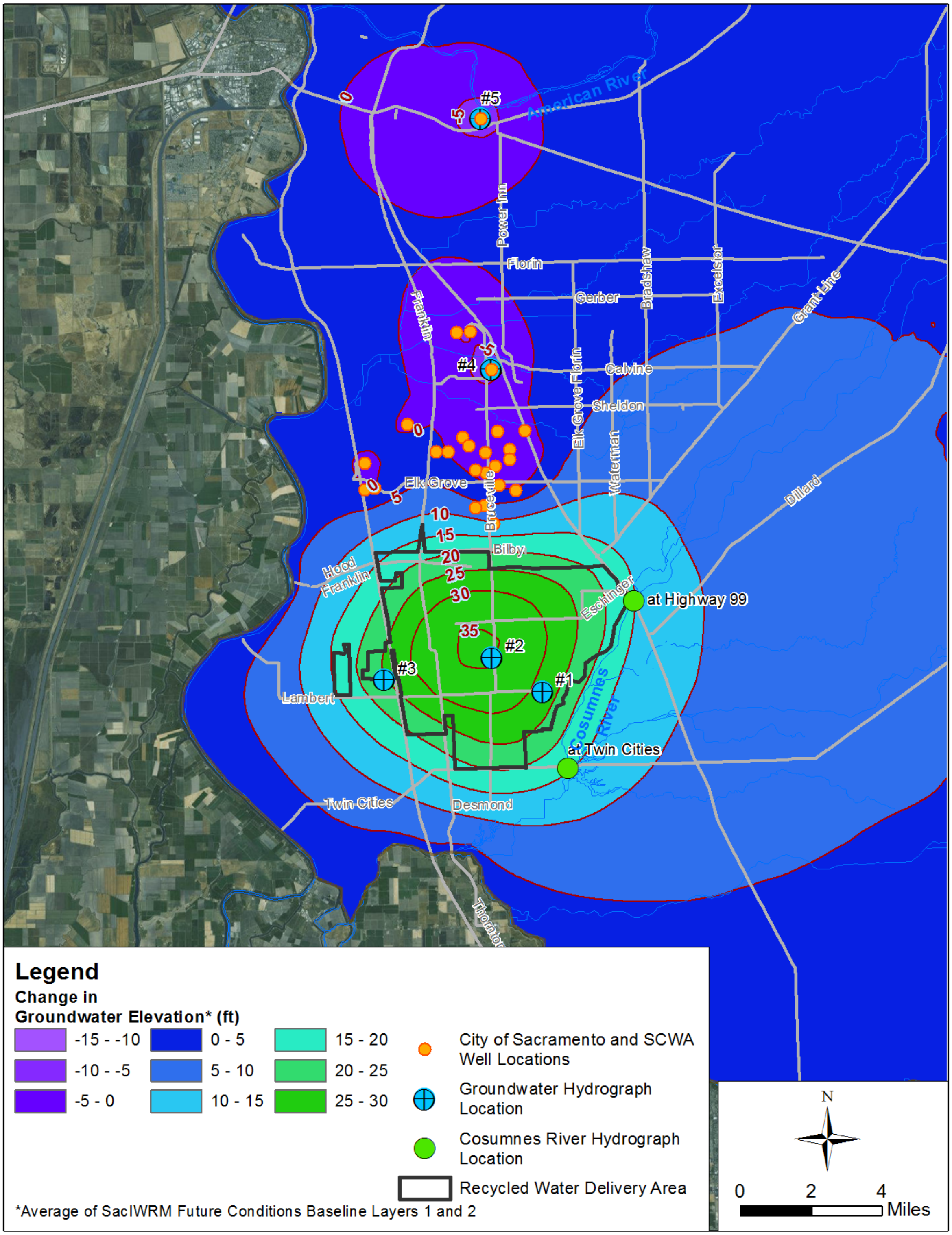


Figure 66: Change in Groundwater Elevation, Dry Year (Fall 1994, 67th Year of Simulation), Project 2070

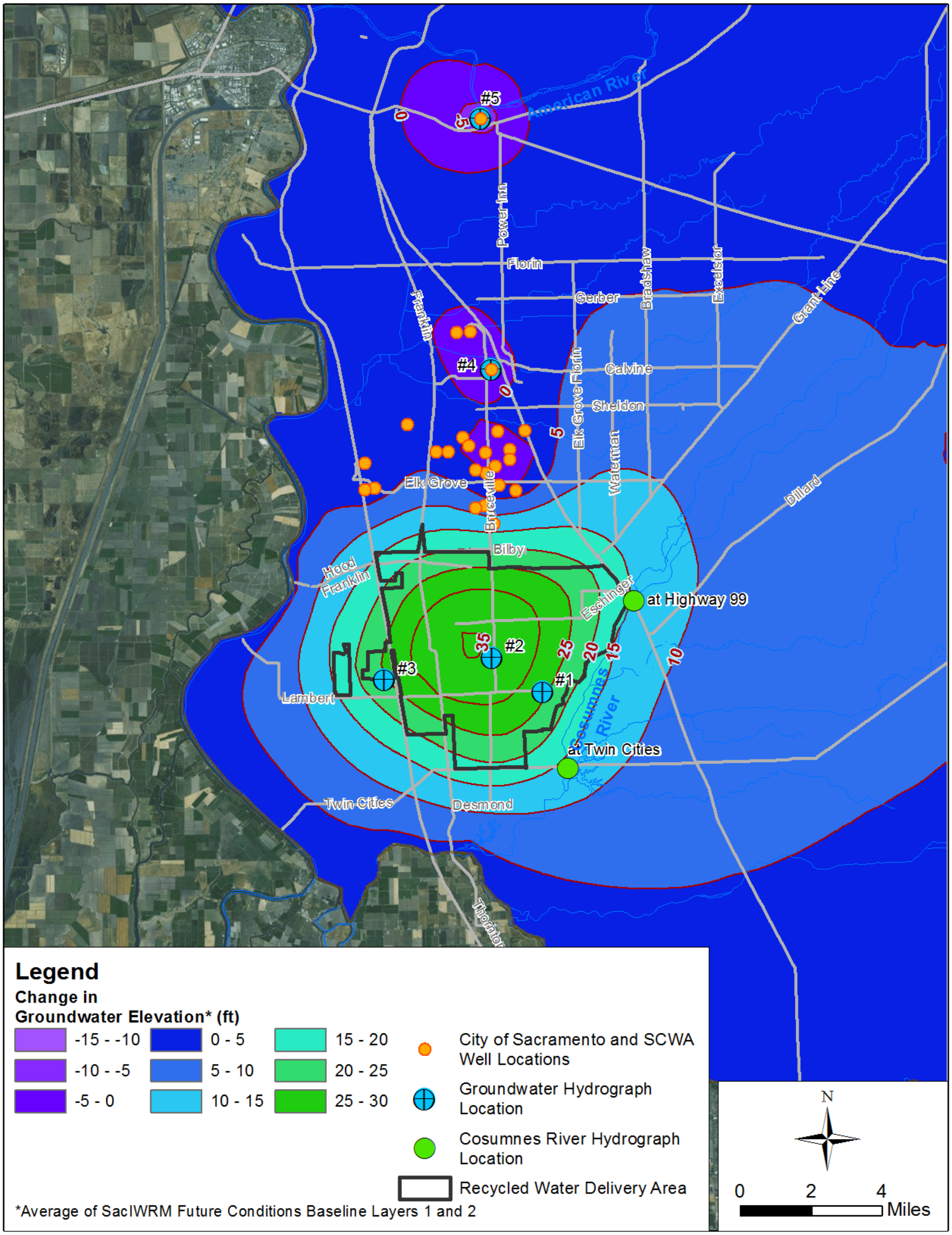


Figure 67: Change in Groundwater Elevation, Normal Year (Fall 2004, 77th Year of Simulation), Project 2070

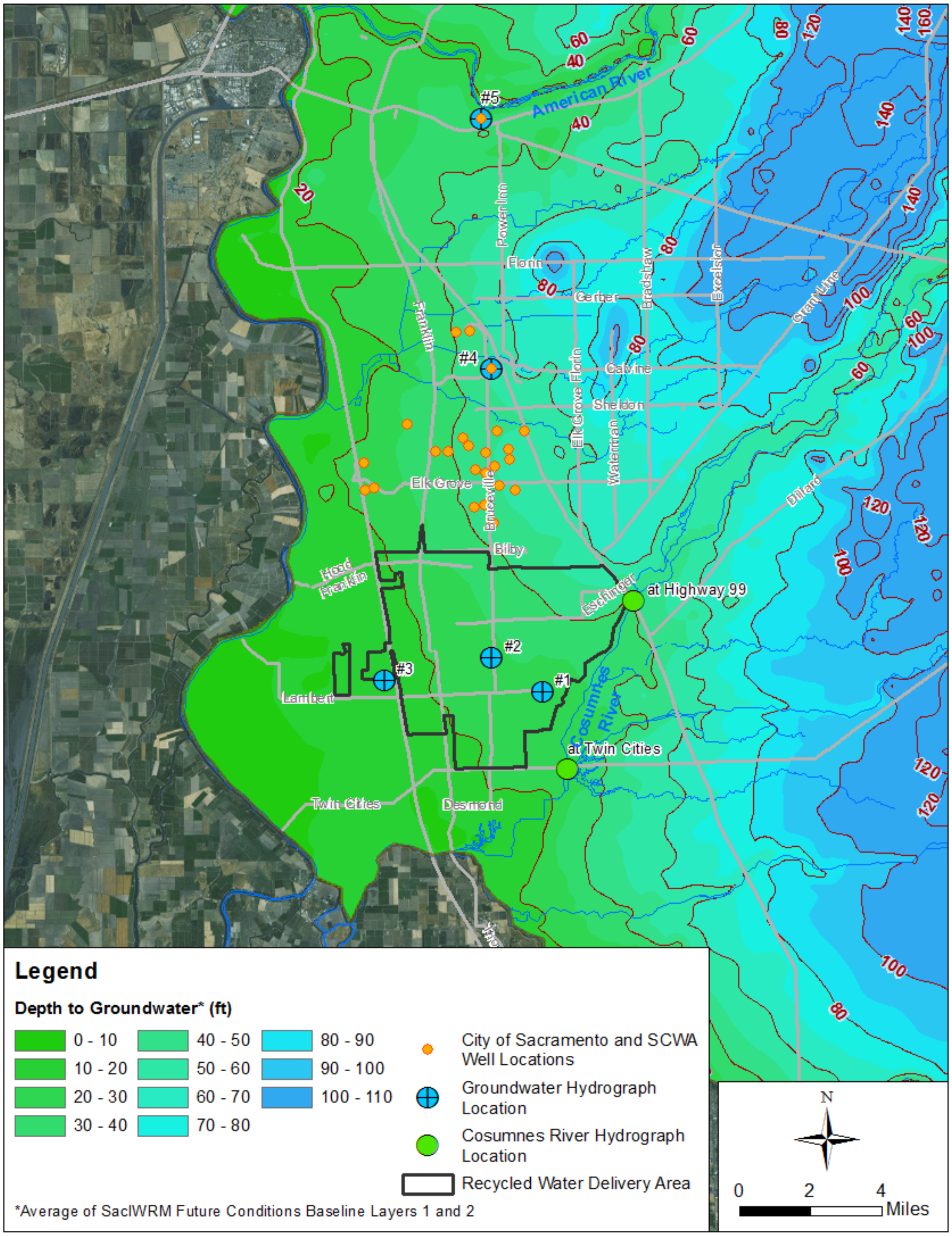


Figure 68: Depth to Groundwater, Wet Year (Fall 1984, 57th Year of Simulation), Project 2070

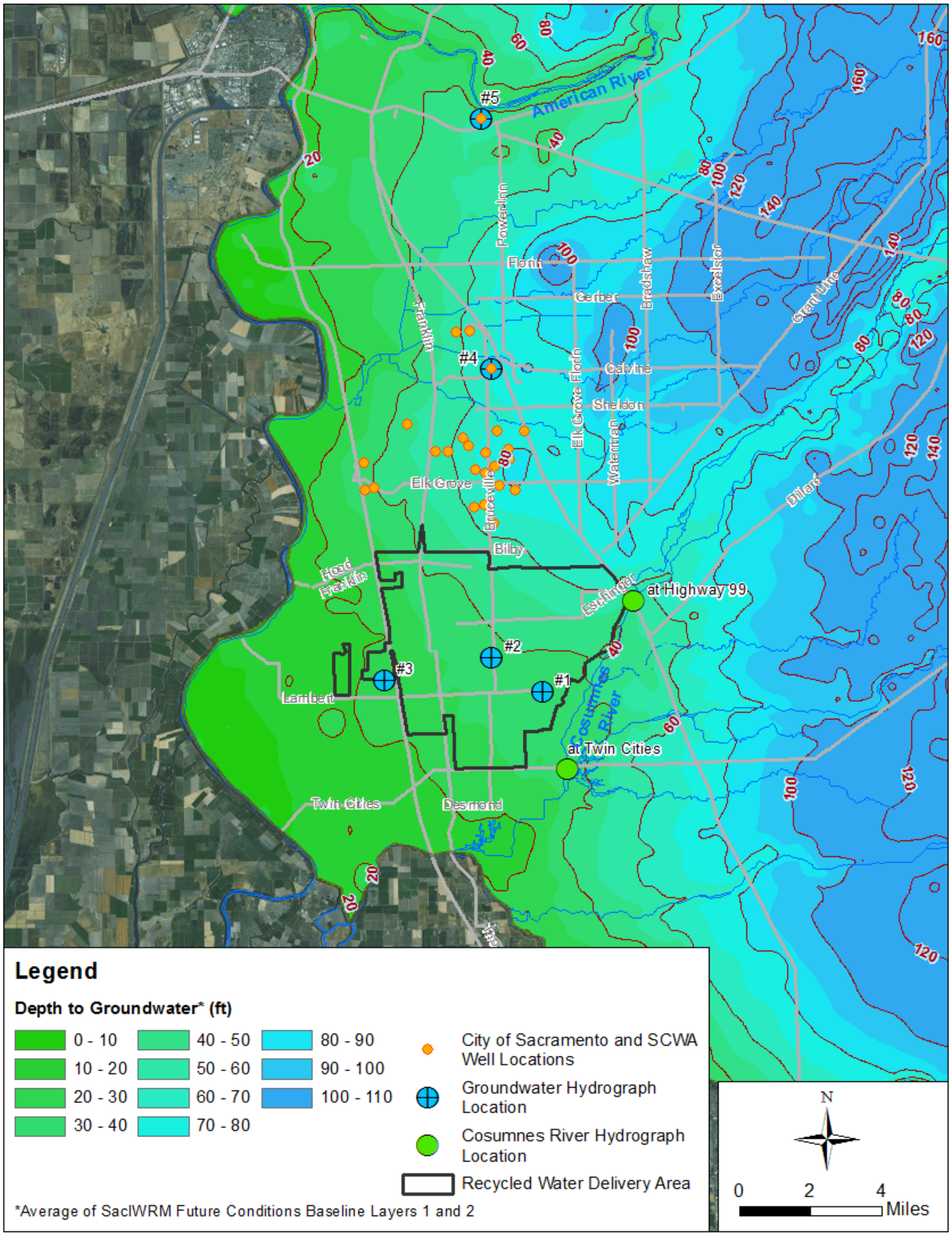


Figure 69: Depth to Groundwater, Dry Year (Fall 1994, 67th Year of Simulation), Project 2070

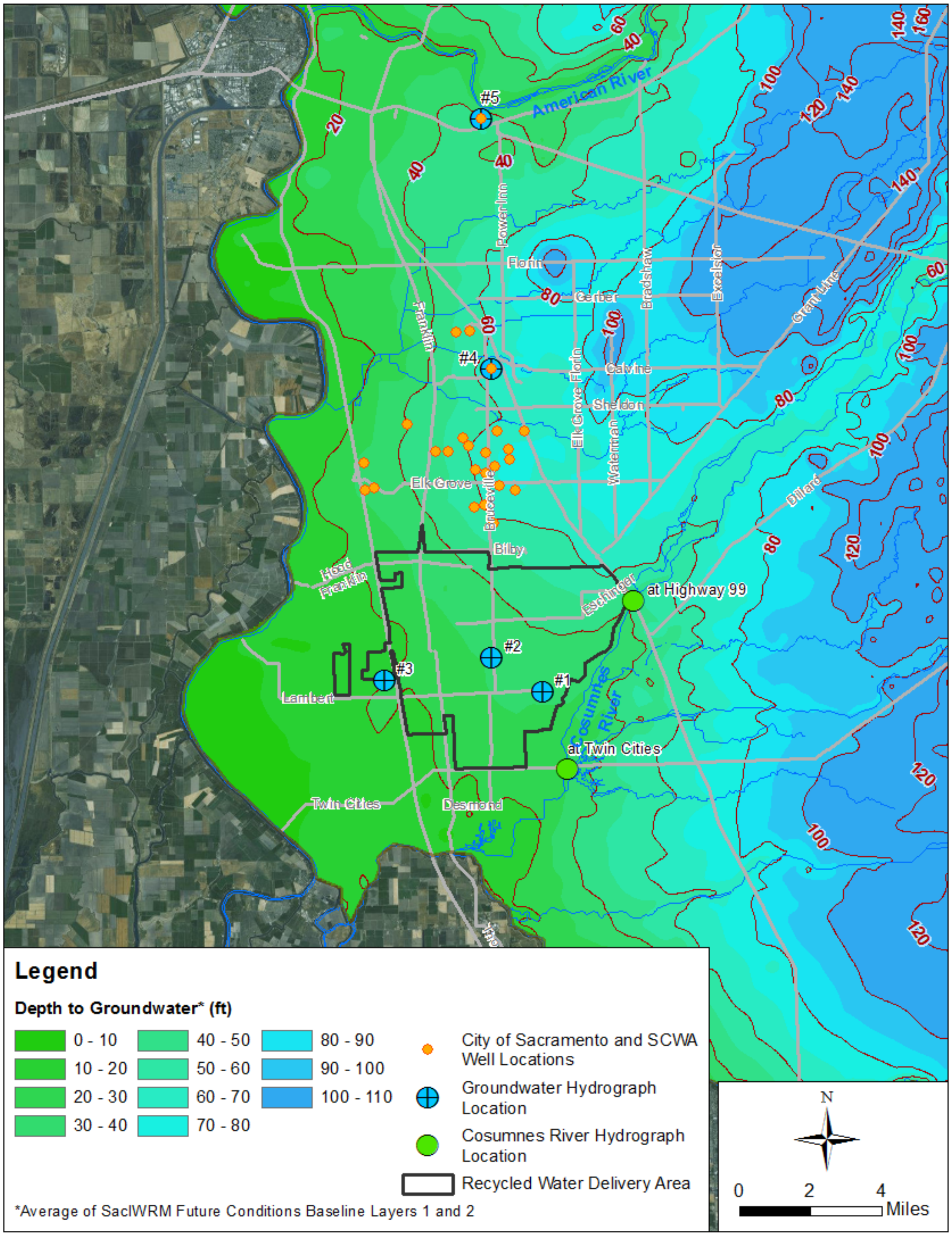
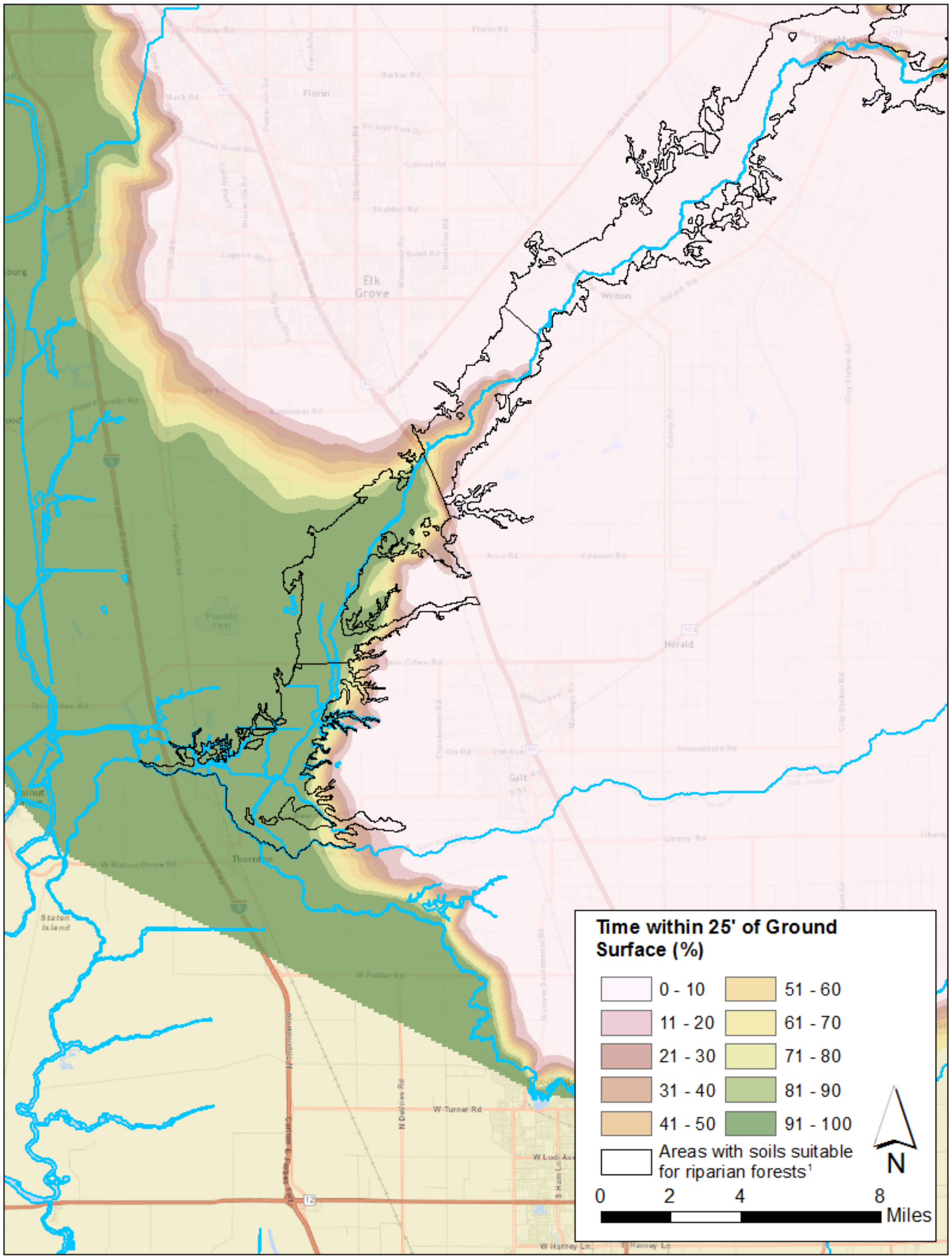


Figure 70: Depth to Groundwater, Normal Year (Fall 2004, 77th Year of Simulation), Project 2070



1. Source TNC 2014

Figure 71: Percent of Time Groundwater Levels are within 25 feet of the Ground Surface, Project 2070

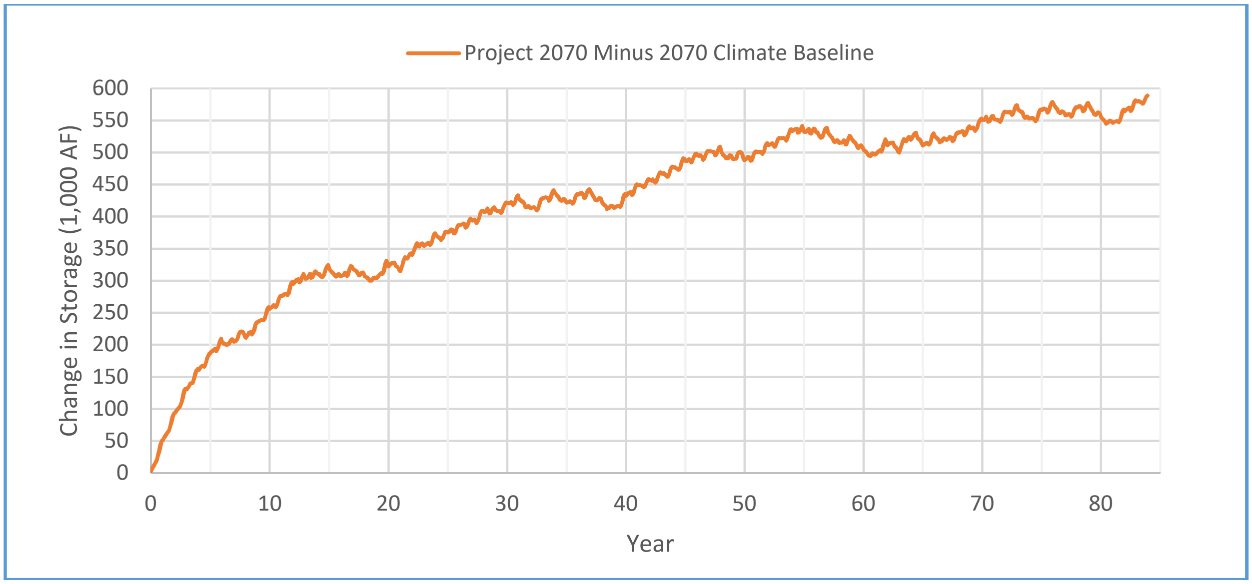


Figure 72: Change in Groundwater Volume, Project 2070 Compared to 2070 Climate Baseline

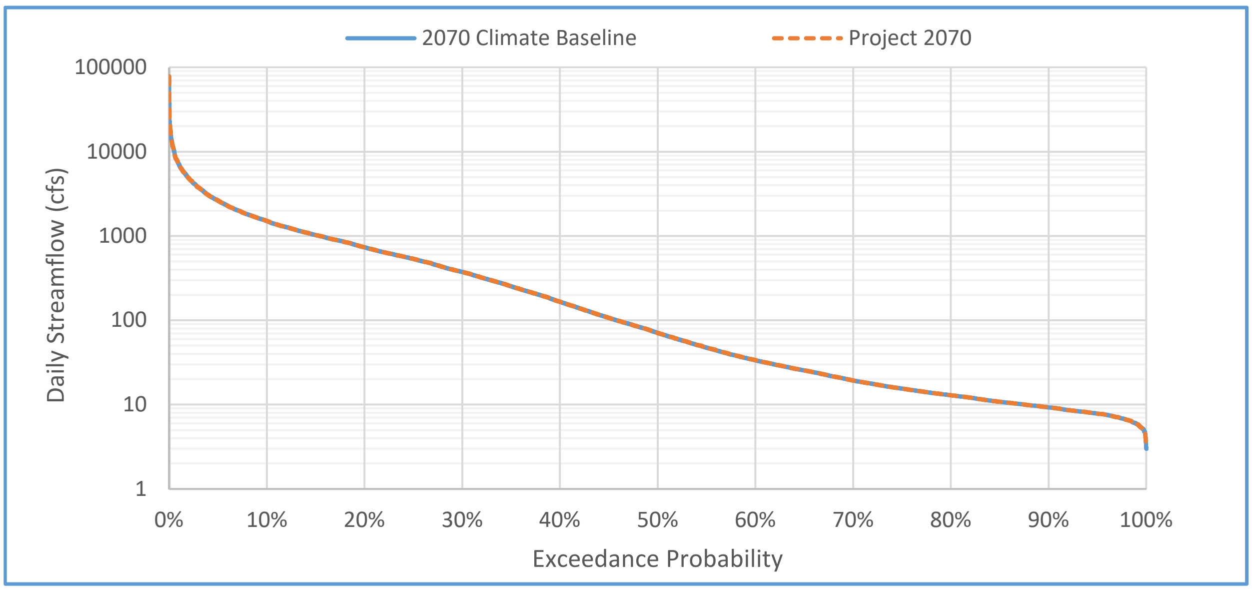


Figure 73: Streamflow Exceedance Chart at Cosumnes River at Highway 99 (McConnell Gage), Project 2070

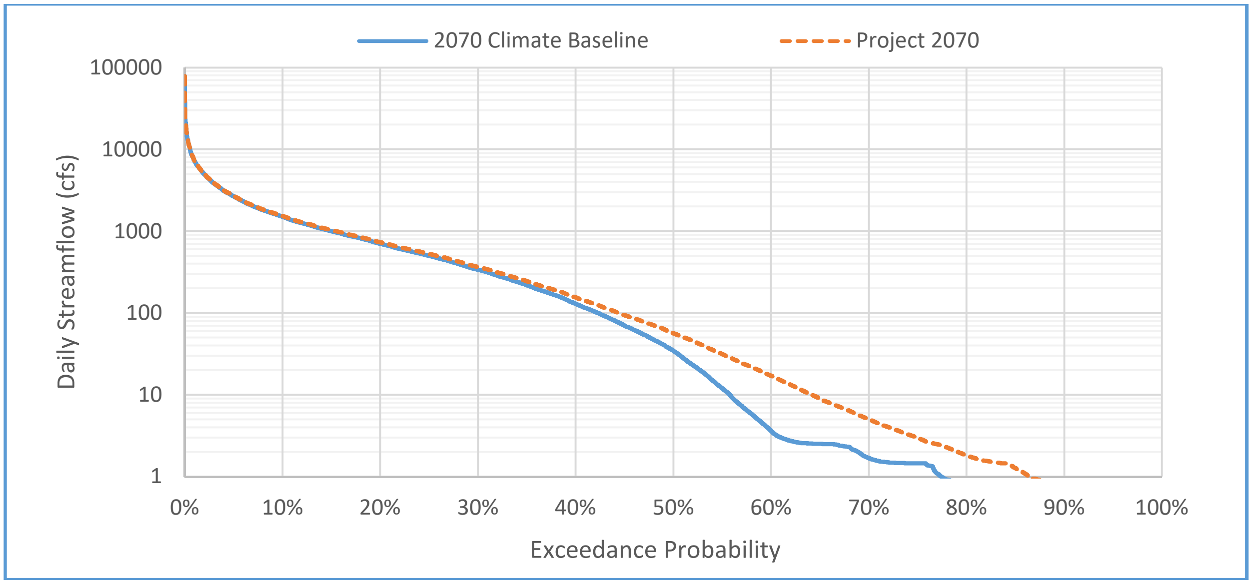


Figure 74: Streamflow Exceedance Chart at Cosumnes River at Twin Cities Road, Project 2070

Table 3: Water Supplies within Project Area, Project 2070

Month	Groundwater Demand (AF/Month)		Surface Water Demand (AF/Month)		Recycled Water Demand (AF/Month)		Total (AF/Month)	
	2030 Climate Baseline	Project 2030	2030 Climate Baseline	Project 2030	2030 Climate Baseline	Project 2030	2030 Climate Baseline	Project 2030
Jan	0	0	0	0	0	3,800	0	3,800
Feb	100	0	0	0	0	3,900	100	3,900
Mar	100	0	0	0	0	4,000	100	4,000
Apr	3,100	200	0	0	0	2,900	3,100	3,100
May	9,700	4,200	0	0	0	5,500	9,700	9,700
June	10,900	5,400	0	0	0	5,500	10,900	10,900
July	12,300	6,700	0	0	0	5,500	12,300	12,200
Aug	8,400	2,300	0	0	0	6,100	8,400	8,400
Sept	4,400	700	0	0	0	3,700	4,400	4,400
Oct	1,600	100	0	0	0	1,500	1,600	1,600
Nov	0	0	0	0	0	3,800	0	3,800
Dec	0	0	0	0	0	3,800	0	3,800
Total	**50,600**	**19,600**	**0**	**0**	**0**	**50,000**	**50,600**	**69,600**

Table 4: Groundwater Storage, Inflows, and Outflows Compared to the 2070 Climate Baseline, Project 2070

Project 2030 Minus 2030 Climate Baseline	Impact on Water Budget for the Entire Model Area (AFY)						
	Groundwater Production	Recharge	Gain from Rivers/Streams	Boundary Inflow	Change in Groundwater Storage	Other	Stream Outflow
Full Simulation	-22,100	19,000	-17,200	-17,100	7,000	100	28,500
First Half	-22,500	19,000	-15,600	-15,300	10,900	300	26,300
Second Half	-21,700	19,000	-18,700	-18,900	3,100	0	30,800

4.3 Integration with CalSim-II

In addition to providing information on the effects of the project on Sacramento area groundwater and surface water resources, SacIWRM modeling was also used to inform simulation of Central Valley surface water resources, including the State Water Project and Central Valley Project, using CalSim-II. The simulated changes in streamflow from SacIWRM were used as input into CalSim-II so that CalSim-II can simulate the effects of the reduced wastewater discharges together with project-related increases in streamflow due to higher groundwater elevation conditions.

Since SacIWRM and CalSim-II simulate over different hydrologic periods, a water-year type analysis was used to pair appropriate SacIWRM output with CalSim-II input. SacIWRM simulates hydrologic conditions from 1970-2011, repeated twice. CalSim-II simulates hydrologic conditions from 1922-2003.

The water-year type analysis allows for the 1970-2011 data from SacIWRM to fully populate CalSim-II input for the 1922-2003 period.

In addition to water-year type, the time since project inception is incorporated into the analysis to properly reflect the distribution of project benefits. As discussed earlier in this section, the effects of the project are highly dependent on how long the project has been in operation, with relatively more benefits to groundwater storage earlier in the project and relatively more benefits to surface water flows later in the project.

A two-part linear regression analysis was performed for each water-year type to allow for the estimation of streamflow benefits at any point in time since project inception and at any water-year type. Within each water-year type, the analysis was performed for each month, January through December. The regressions were based on the SacIWRM-simulated increases in streamflow due to the project. For example, the regression for dry year-type Aprils would be based on monthly increase-in-streamflow data from SacIWRM for all dry year-type Aprils (simulation years 13, 19, 33, 39, 40, 41, 55, 61, 75, 81, 82, and 83). The regression analysis run on these dry year-type April data allows for smoothing, interpolation, and extrapolation. It was assumed that the percent of benefits accruing to surface water within the model area is the same as the percent accruing outside the model area, thus that portion of benefits outside the model area (change in inflows) was allocated to streamflow benefits, in addition to the direct simulation of increased streamflow within the model area. The results of the regression analyses are a series of two-part linear regression analysis for each month and for each water-year type, allowing incorporation of the monthly streamflow increase for any month into CalSim-II.

The two parts of the "two-part" linear regression analysis refer to two periods of project operation: "ramp up", where groundwater levels are rising as a result of project recharge and "near-equilibrium", where groundwater levels are no longer rising rapidly and the majority of project benefits are being accrued to the surface water system. For the regression analysis, the first 25 years of SacIWRM simulation were considered the ramp-up period and the remaining 59 years were considered the near-equilibrium period. This was based on an analysis of the change in increases-in-streamflow over time, how they increase quickly over the first 10 years and then begin to approach an equilibrium after 25 years of project operation. For the ramp-up, a linear regression was developed for the first 25 years, beginning at a 0 AFY increase in streamflow at year 0. For the near-equilibrium condition, a linear regression was developed for the final 59 years, with a slope of 0 (horizontal line). Input data for CalSim-II were identified by reading the value from the regression at the appropriate time period for the year-type and month.

5 Summary

Modeling results using the SacIWRM show the benefits of in-lieu and wintertime irrigation of recycled water by the project. Initial benefits from recharge are accrued primarily to groundwater in storage, while later benefits are accrued primarily to surface water flow. Table 5 summarizes the potential benefits from the project with respect to the groundwater storage, streamflows, and riparian benefits.

Table 5: Groundwater Storage, Streamflows, and Riparian Benefits – Project 2030 and Project 2070 Scenarios

	Project 2030	Project 2070
Groundwater Storage (AF) [1]	450,000	590,000
Cosumnes Streamflows (cfs) [2]	3 - 22	0.4 - 17
Riparian Benefits (acres) [3]	15,500	13,200
Gain from Rivers/Streams (AFY) [4]	-17,200	-20,700

Footnote:

(1) This represents the change in storage over the entire simulation period relative to the climate change baseline conditions.

(2) This represents the average daily flows in the Cosumnes River over the entire simulation period relative to the climate change baseline conditions, based on the model results at two locations (Highway 99 and Twin Cities Road).

(3) This represents areas that meet the riparian threshold of groundwater elevations within 25 feet of the surface 90 percent of the time over the entire simulation period.

(4) The negative sign represents the reduction from gain from rivers/streams to groundwater basin on an average annually relative to the climate change conditions.

5.1 Recharge Components

Project 2030 and 2070 Scenarios improve groundwater and surface water conditions in and around the project area. The improvements in groundwater conditions occur relatively early in the modeling simulation. Groundwater elevations increase most near the center of the project area, up to approximately 35 feet after 15 years and generally stabilizing thereafter. Groundwater elevation increases are smaller towards the boundaries of the project area showing long-term project-related increases of approximately 25-30 feet. The area with at least 15-20 feet increase in groundwater elevations extends to just beyond the project boundaries. Hydrologic conditions have only a small impact on the project-related increases in groundwater elevations under the Project 2030 Scenario, with slightly larger increases under the 2070 Baseline compared to the 2030 Baseline during dry periods as opposed to wetter periods. During the wet periods, the overall increase in groundwater elevations spread over larger areas beyond the project area compared to the normal and dry periods. Overall, the increase in groundwater elevations during each water year type is greater for the Project 2070 Scenario than the Project 2030 Scenario. As groundwater levels rise, recharge from surface water courses, notably the Cosumnes River, are reduced resulting in long-term project benefits as increased surface water flows.

In-lieu and wintertime irrigation results in benefits to groundwater storage and streamflow, with early-year benefits primarily to groundwater storage and later-year benefits primarily to streamflow. Both Project 2030 and 2070 Scenarios include the in-lieu recharge and wintertime irrigation components of the Project. Modeling results show an increase in groundwater in storage and groundwater elevations in and around the project area. Hydrographs, water budgets, and plots of groundwater storage show that early year benefits are focused on increased groundwater in storage and associated higher groundwater elevations. As the groundwater system approaches a new equilibrium, the higher groundwater conditions interact with the surface water system, resulting in decreased recharge from rivers, primarily the Cosumnes River, to groundwater. This shifts the focus of the benefits in later years from increased groundwater in storage to increased streamflow. Additionally, the higher groundwater conditions interact with the surrounding basins, benefiting groundwater in storage and streamflow conditions in those basins as well. The rate of groundwater storage increase for the Project 2030 and 2070 Scenarios is similar in the first 10 years of the simulation and continues at a slightly higher rate in the Project 2070 Scenario for the remaining of the simulation. In the first 10 years of the simulation, the recharged water results in approximately 245,000 AF increased storage under the Project 2030 Scenario and 256,000 AF under the Project 2070 Scenario. This is approximately 50% of the recharged water resulting in increased storage in the first 10 years of the simulation, with the remainder resulting in increased streamflows or increased storage in adjacent basins. As groundwater levels rise with the continued recharge, less of the recharge contributes to groundwater storage and more contributes to streamflows or storage in adjacent basins. In the first 20 years of the simulation, 1,000,000 AF is recharged with an increase in groundwater storage of approximately 290,000 AF under the Project 2030 Scenario and 320,000 AF under the Project 2070 Scenario. This is approximately 29% of the recharged water resulting in increased storage under the Project 2030 Scenario compared to 32% under the Project 2070 Scenario. The rate of increase in groundwater storage continues at a slower rate, as reflected in the trends shown in Figure 53~~Figure 53~~ for the Project 2030 Scenario and in Figure 72~~Figure 72~~ for the Project 2070 Scenario. In the final 10 years of the simulation, 500,000 AF is recharged with an increase in groundwater storage of approximately 27,000 AF under the Project 2030 Scenario and 36,000 AF under the project 2070 Scenario. This is approximately 5% and 7% of the recharged water resulting in increased storage under the Project 2030 and Project 2070 Scenarios, respectively, with the remaining 95% and 93% resulting in benefits to storage and streamflow both inside and outside of the model area.

In-lieu and wintertime irrigation provides benefits to streamflow in Cosumnes River and riparian habitats along the Cosumnes River. Streamflows in the Cosumnes River would be higher under the project during low-flow events based on the model results at Twin Cities Road (Figure 55~~Figure 55~~ and Figure 74~~Figure 74~~, with location shown on Figure 37~~Figure 37~~). On an average, the daily flows would be higher by approximately 22 cfs under the Project 2030 Scenario and 17 cfs under the Project 2070 Scenario. While there is small to negligible difference in streamflows in the Cosumnes River at Highway 99 (Figure 54~~Figure 54~~ and Figure 73~~Figure 73~~, location shown on Figure 37~~Figure 37~~), both the Project 2030 and 2070 Scenarios show slightly higher flows than the corresponding climate change baseline conditions, showing benefits to streamflows during low-flow events.

Project 2030 Scenario increases area suitable for riparian habitat from 7,100 acres to 15,500 acres compared to the 2030 Climate Baseline. Under the Project 2070 Scenario, area suitable for riparian increases from 4,800 acres to 13,200 acres relative to the 2070 Climate Baseline.

5.2 Extraction Components

Extraction of banked water can provide critical dry year supplies for a variety of potential uses. The recovery of the project banked groundwater could allow for the sale of the surface water to other entities and/or improved reliability in the region. The proposed project assumes extraction using the existing wells by the City of Sacramento and SCWA, or their respective wholesale customers, to pump the project banked groundwater while reducing their surface water use. A variety of different users could extract the banked water, and they are likely to be located in a similar distance as the City of Sacramento and SCWA. Therefore, the results of this project scenario could be used to provide some level of understanding of the impact of those different users. Regional San has ongoing discussions of the proposed project banking and recharge operations with the Sacramento Central Groundwater Authority, which includes a broad consortium of these agencies, including the City of Sacramento and SCWA. Although no final agreements have been reached with these agencies, the proposed project banking and recharge operations are consistent with the conjunctive use plans of these agencies in the region. The proposed project extractions will be further refined in coordination with the Sacramento Central Groundwater Authority and its member agencies as a water accounting framework and groundwater bank is developed, along with additional environmental analysis. Benefits in the project area and potential impacts to other areas would vary depending on the method, location, magnitude, and use of potential extraction of banked water as the proposed project extractions will be further refined in coordination with the agencies as a groundwater banking program is developed.

Extraction through groundwater wells north of the project area maintains most of the Project benefits in and around the project area.

Project 2030 and 2070 Scenarios both simulate potential extraction of water banked under the project hypothetically using the existing wells located in the southern portions of the service areas of the City of Sacramento and SCWA. It is assumed that the City of Sacramento and SCWA, or their respective wholesale customers, would have the capability to extract up to 30 percent of the banked water.

Extraction of up to 30 percent of the banked water under the Project 2030 and 2070 Scenarios results in somewhat reduced benefits in the in-lieu recharge area and lower groundwater elevations in the extraction area. However, regional groundwater in storage remains above the 2030 and 2070 Climate Baseline levels at all times, with a long-term accrual of groundwater to the basin between approximately 450,000 AF under the Project 2030 Scenario and 590,000 AF under the Project 2070 Scenario. Groundwater elevations within the in-lieu recharge area rise approximately 15-35 feet both under the Project 2030 and Project 2070 Scenarios. Groundwater elevations decline near the extraction wells up to approximately 10-15 feet compared to the 2030 and 2070 Climate Baselines. However, these groundwater elevations recover quickly to baseline conditions or stay above the baseline over subsequent years without extraction. This decline results in a relatively small increase in recharge from the Sacramento River and increased subsurface flow from subbasins to the west. Overall, the groundwater extraction in areas further away from the project area would have less impacts on the overall project benefits gained from the groundwater recharge.

Appendix A. Year Types

For this effort, a water year type index is used to identify dry hydrology where project deliveries would be simulated as curtailed under the both Project 2030 and 2070 Climate Baselines (see Section 3). As the area between the American and Cosumnes Rivers receives surface water supplies from both the Sacramento River and the American River, a composite water year type index (SacIWRM index) of both rivers was developed to determine hydrologic year types for use in the SacIWRM model. The SacIWRM Index is based primarily on the American River Index, except for the Drier Years, which is a composite of the American River and the Sacramento River indices. Table 1 shows the SacIWRM Index for the 1970-2011 hydrology that includes 23 Wet Years, 9 Normal Years, 3 Drier Years, 6 Drier & Critical Years, and 1 Driest Year.

Some simulations have components that occur within the 30 percent driest years. The 30 percent of the driest years, based on the index value, are all the Drier, Drier & Critical, and Driest Years within the 1970-2011 hydrologic record, as well as 2 normal years. The Normal Years were selected based on the lowest unimpaired inflow to Folsom Reservoir for March through November, which is the basis for the American River Index. The 30 percent driest years are 1976, 1977, 1985, 1987, 1988, 1990, 1992, 1994, 2001, 2004, 2007, and 2008, as shown in Table 1.

Table 1: SacIWRM Index of Hydrologic Year Types

Year	SacIWRM Index	Year	SacIWRM Index	Year	SacIWRM Index	Year	SacIWRM Index
1970	Normal	1981	Normal	1992	Drier & Critical	2003	Wet
1971	Wet	1982	Wet	1993	Wet	2004	Normal
1972	Normal	1983	Wet	1994	Drier & Critical	2005	Wet
1973	Wet	1984	Wet	1995	Wet	2006	Wet
1974	Wet	1985	Normal	1996	Wet	2007	Drier
1975	Wet	1986	Wet	1997	Normal	2008	Drier & Critical
1976	Drier & Critical	1987	Drier	1998	Wet	2009	Normal
1977	Driest	1988	Drier & Critical	1999	Wet	2010	Wet
1978	Wet	1989	Wet	2000	Wet	2011	Wet
1979	Wet	1990	Drier & Critical	2001	Drier		
1980	Wet	1991	Normal	2002	Normal		

Footnote: Driest 30 percent of years are highlighted in light blue.